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Jakob Kunz
1874-1938

By JOEL STEBBINS

The career of Jakob Kunz is an illustration of the cosmopolitan character of science. Born and educated in Switzerland, he pursued advanced study in England, migrated to the United States, then returned several times to Germany for further study. Although his training and tastes were in theoretical physics, he often maintained that the best things in physics are up in the sky. His interests seemed to include all branches of science and all fields of human endeavor.

He was born in Brittnau, Aargau, Switzerland, on November 3, 1874, the son of Jakob and Anna Marie Weber Kunz. His father was a small farmer, who at times did weaving in a nearby factory or on the hand looms at home. Jakob was educated in the public schools, and from the time he entered the gymnasium he supported himself by tutoring. He entered the Eidgenössisches Polytechnikum at Zurich, where he received the degree of B.S. in 1897. For the next three years he was a chemist in the Gesellschaft für Chemische Industrie at Basel, and this experience in industrial science was of great value in later years. He then returned to the Zurich Polytechnikum as instructor in physics, received the Ph.D. degree in 1902, and continued as private docent until 1907.

The next year was spent at the Cavendish Laboratory in Cambridge, England, in research under the guidance of J. J. Thomson. While at Cambridge he became friends with Dean Thomas F. Holgate of Northwestern University, who promised to help Kunz find a position if he should ever come to America. Kunz always remembered the year at Cambridge as one of the best of his life, and after a short sojourn at home he finally decided to try America. He turned up in Evanston in the summer of 1908 to remind Dean Holgate of his promise about a position. As Kunz had arrived almost without resources, Dean Holgate was put to some vigorous efforts to help him. Late in the summer a position was found as instructor in physics at the University of Michigan. Before the first year was over Michigan was ready to promote him to an assistant professorship, but a more attractive offer came from the University of Illinois, where President Edmund J. James was looking for a certain amount of European influence in the rapidly developing graduate work of that institution. Kunz's appointment at Illinois was in mathematical physics, and here he remained as assistant professor, associate professor, and professor for the remainder of his career.

From the beginning he was assigned only advanced and graduate

classes, as his talents were certainly not for elementary instruction. Most of the graduate students of the department naturally came to his courses, and though his specialty was theoretical physics he undertook to see a number of candidates through their experimental work for the doctor's degree.

In teaching, Kunz's work was marked by a thorough knowledge of his subject and effective presentation. He was a good experimenter and his background of theory always gave him an insight to the meaning of experimental results. His advice on scientific problems was soon in demand by colleagues in his own and in other departments. In some early work with the selenium cell the present writer remembers calling on Kunz for advice about a certain matter. In only a few minutes' conversation the trouble was cleared up, and after the proper changes had been made in the experimental setup, that particular difficulty was banished for all time.

It was in the construction of photoelectric cells, which after all was only a side line with Kunz, that he made his contribution to astronomy. In the autumn of 1911 he suggested the possibility of using a photoelectric cell, made from one of the alkali metals, for photometric measures of the light of the stars. In fact, he promised to make such a cell as soon as he could get around to it. This work was held in abeyance until 1913 when we began a coöperation which was to last for twenty-five years.

Kunz's procedure in the construction of a photoelectric cell was based on the method introduced by Elster and Geitel many years before. The alkali metal was distilled onto a silvered interior surface of a glass bulb, and after evacuation a glow discharge in hydrogen produced a colloidal form of the metal which is very sensitive to light. Many experiments were made on the metals, sodium, potassium, rubidium, and cesium. After the metal is sensitized, the introduction of a small amount of inert gas into the bulb increases the photoelectric current by gas amplification, and tests were made with helium, neon, and argon. In all this work the effort was to get a favorable relation of "signal to noise," that is, a large light effect with a small dark current or other disturbance. After many experiments Kunz found that the best cells were made in a bulb and tube of fused quartz, the high insulation of which brought the dark current down almost to zero. Some of Kunz's cells have shown a dark current as small as 10^{-17} ampere, where the photocurrents from faint lights were of the order 10^{-15} to 10^{-14} ampere. The ordinary commercial cell may have a dark current as large as 10^{-9} ampere.

In all of the experiments on photocells Kunz did much of his own glass blowing and the other manipulation. As has been found by others, the really exceptional cell is both the hope and the despair of the investigator. It was always a simple matter to produce a cell of fair or average sensitivity, but the difference between a fine cell and an ordinary one may well be represented by a factor of 5 or 10 in the effective sensitivity.

Thus the production of the best cells was more of an art than a science. Despite the amount of experimentation on photocells that has been done in industrial laboratories since their application to sound pictures, the simple handmade cells by Kunz are still the best that we have ever tested for faint sources like the stars. These cells have been used at half a dozen American observatories, and by many individuals working in other fields than astronomy. The ordinary cell used for the movies usually has a dark current which is greater than the light effect from a star like Sirius at the focus of a moderate sized telescope. While the thermionic emission of such a cell may be greatly reduced by refrigeration with dry ice or liquid air, for ordinary work the non-refrigerated photocell is much more convenient. That there will be better cells produced in the near future, no one was more hopeful than Kunz himself. In fact, up to within a few weeks of his death, he was experimenting with J. T. Tykociner on extra-sensitive cells. They had produced cells several times more sensitive than any previously available, but the problem was to keep them permanent. The cells unfortunately would lose their sensitivity slowly with the passage of time.

Dr. Kunz and the present writer attempted the photoelectric measurement of the total light of the solar corona at four different eclipses, at Rock Springs, Wyoming, in 1918, at Catalina Island in 1923, at Middletown, Connecticut, in 1925, and at Lancaster, New Hampshire, in 1932. To these should be added the expedition to Peru in 1937 where a Kunz cell was used though he could not undertake to go to the altitude of 14,000 feet. On these expeditions he will be remembered by his colleagues as a quaint figure and an indefatigable worker. Although the problem in experimental physics was an extremely simple one, he welcomed the part of taking laboratory readings in the camp surroundings. The sky was clear at three of the eclipses, and the solar corona was found to give half the total light of the full moon, with little variation from one eclipse to the next. In 1937, when color measures were added to the program, the quality of the coronal light was approximately the same as that of the sun over the observed region of the spectrum.

It was characteristic of Kunz that in the intense concentration of reading a galvanometer during the total phase of an eclipse he should pay strict attention to the work in hand, and he sometimes humorously remarked, "Never have I seen the solar corona."

He was also led into coöperation with other colleagues in the application of photoelectric cells. He worked with J. T. Tykociner on sound motion pictures, and with V. E. Shelford on the measurement of solar radiation at different depths under water. In all this coöperative work there was only one personal difficulty which was likely to arise. Kunz would sometimes suggest that his own name be left off the final publication. When confronted with an ultimatum, rather than have a fuss he would allow his name to be used.

Because of the wide range of Kunz's interests and his many contacts

it was natural that his services would be in demand elsewhere. Once, after declining an attractive offer of a research position in a commercial laboratory, he remarked that he had had previous experience in industrial research and that such a proposal as doubling his salary was not enough for the sacrifice involved. If they would make it say five times as much, he might be willing to consider it. After traveling to different parts of the country on the eclipse expeditions there were two activities that Kunz would often undertake on the way home. One was to look up some of his old students who were active in different research positions, and the other was to try to collect the money for photoelectric cells which he had inadvisably sent to irresponsible individuals who had imposed upon his good nature.

Besides articles on photoelectricity, Kunz published numerous papers on magnetism, on the coronal discharge, and on other subjects in theoretical physics. In 1907, as an outcome of his work in Zurich, was published a textbook "Theoretische Physik auf mechanischer Grundlage," and he left an uncompleted work in which he had hoped to bring many of the modern experimental results into conformity with classical physics.

Kunz was never reconciled to the drastic changes that have come about in modern physics. He had often referred to the two physicists who most influenced his thought as J. J. Thomson and Arnold Sommerfeld. It was probably from the English school that he derived a strong preference for a picture or model for a physical concept rather than what he called some meaningless equations. Although Kunz liked to declaim against the trends of modern physical thought, his own knowledge was on such a good foundation that he never became unsound. He did not like the mess that he thought physics had got into, and he tried his best to get it back into the old ways.

Kunz always kept an affection for his native land. He returned to Switzerland in 1913 to get his wife, Anna Bolliger. The family life with two daughters, Anna Marie and Margaret, was ideal. As often as he could earn sabbatical leave, every seven years, they went back to the old home, he to renew his studies, usually with Sommerfeld at Munich to get the latest applications of quantum theory and wave mechanics.

He had the proverbial Swiss talent for languages. In the classical gymnasium he studied for years Latin, Greek, and Hebrew, the last because he at one time hoped to be a minister. He spoke fluently English, German, French, and Italian, and could do something with Spanish. Even during his last illness he continued at Russian!

Kunz had the proverbial simplicity of a true scientist; he was liberal in politics and religion, and was always an enthusiastic worker for social justice. It used to be a puzzle why, either at home or on an expedition, the cranks and queer people were attracted to him as to a magnet. On analysis this was seen to be due to his kindly nature, for he would listen patiently to everybody, no matter how absurd their views, and

such interviews were naturally repeated.

He was never really Americanized in many ways, such for instance as in driving an automobile. He considered a bicycle plenty good enough for the half mile on level pavement between home and office, and who shall say he was not right? He did not enjoy ordinary sports or games, in fact he never learned to play much of anything, but he did like to work in his garden. He was not interested in trivial things, but was always ready for a good strenuous discussion in philosophy, religion, or politics.

During the last half dozen years of his life Kunz had various warnings that he would have to go at a slower pace, and he did so with regret. He worked faithfully to within a few weeks of the end, and was taken by a heart attack on July 18, 1938, at the age of sixty-four. It was natural that some of his important work should be interrupted, but that was the way in which he would be expected to go. He was a sincere scientist, a true internationalist, and a faithful friend.

MADISON, WISCONSIN, January, 1939.

The Salina (Utah) Meteorite

By STUART H. PERRY

The small meteoritic fragment here described is a weathered remnant of a much larger mass of meteoritic iron, the metal having changed to limonite except for a few minute portions that remain unaltered.

It was sent to the writer in 1928 by William J. Burns, a mining executive then living at Salina, Utah. It had been found about twenty years earlier by Walter Johnson while herding sheep in the Pahvant Mountains about 15 miles from Salina, and given by him to Mr. Burns' father, Miles L. Burns, now deceased.

According to statements from the few persons who knew the circumstances, Mr. Johnson came across a number of fragments of this material on a low rounded ridge and brought several of them to a sheep corral nearby. He showed them to Miles L. Burns, who was a well-informed mining prospector, and asked him what they were. The latter visited the spot where they were found and told another son, Vivian Burns, that there was a small depression in the stony earth of the ridge around which were scattered numerous fragments which he correctly judged to be the weathered remains of meteoritic iron, similar to specimens he had seen from Canyon Diablo—evidently referring to the "shale balls" found in that locality. He indicated that some of the fragments were four or five pounds in weight, scattered over a space a few feet in diameter. He brought down several samples which he and his sons pulverized, finding some granules of malleable metallic iron.

The discovery is also recalled by Ernest Herbert, who now owns a ranch in the valley about five miles from the spot, and who for eleven

years was in the Forest Service, his work including the making of detailed maps of that vicinity. He entered the service in May, 1908, and that season while he was stopping at Johnson's camp on the sheep range, about half a mile from the corral referred to, the latter showed him some pieces of the iron-bearing material. He broke up one, finding a small nugget of iron which he pounded into a disc the size of a dime.

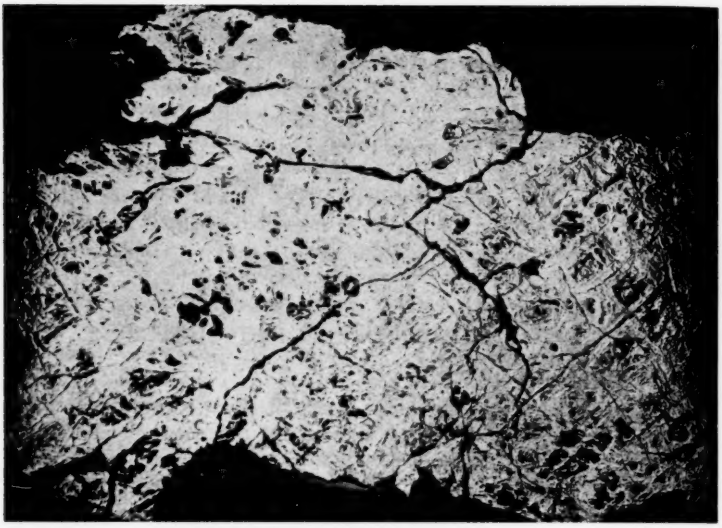

FIGURE 1

PORTION OF POLISHED SURFACE MAGNIFIED 2½ TIMES, CENTRAL ILLUMINATION.

No further information could be obtained, nor could any other specimens be located.

In 1930 at the writer's instance Mr. Johnson, accompanied by W. J Burns and Vivian Burns, revisited the locality in the hope of rediscovering the spot where the specimens were obtained. Mr. Johnson felt sure that he could readily find it, but to his surprise and disappointment no indication of such a spot could be seen, though the party made a long and careful search.

Information received from Mr. Herbert that he also had seen the specimens at Johnson's camp suggested the possibility that they might have come from another ridge nearer to the camp, instead of the similar ridge near the corral. This prompted the writer to go over the ground again in September, 1935, accompanied by Messrs. Herbert, W. J. Burns, and Vivian Burns.

It is in unsurveyed territory in Section 36, Township 21 south, Range

3 west, Salt Lake meridian, on the eastern slope of the Pahvant Mountains about 4 miles south of Mt. Catharine and 3 miles west of Beehive Peak. The terrain, lying at an altitude of about 9,000 feet, consists of rounded ridges of stony earth affording pasturage and in many places covered rather thickly by scrub growth, with occasional clumps of aspen on the lower slopes. The spot is about 4,000 feet above the valley and is reached by trail up a canyon opening near Mr. Herbert's ranch.

FIGURE 2

MINUTE AREA OF KAMACITE AND RHABDITE CRYSTALS IN GROUND OF LIMONITE.
The kamacite shows two Neumann lines. Magnification 100.

FIGURE 3

AN AREA SIMILAR TO FIGURE 1. Oxidation has started around several rhabdite crystals within the kamacite area. Magnification 250.

Mr. Johnson's camp site of 1908 was readily found, with his name and the date carved on an aspen tree; but the character of the land at that point indicated clearly that the specimens must have been found on the other ridge, near the corral, and had been carried from there to the Johnson camp. The principal search therefore was directed to the latter ridge, which is near the head of Chalk Creek canyon and about one-half mile east of Indian Spring.

The ridge, which runs north and south, is about a quarter of a mile long and rises perhaps 100 feet above a small grove of aspen near its northern end, that spot being known locally as Jack's Corral. The surface of the ridge is stony earth, with occasional white stones and exposed patches of white rock, such as the late Mr. Burns had mentioned in describing the place.

The whole ridge is covered with clumps of scrub growth, the bushes reaching a height of six or eight feet. The writer and his three com-

panions—all experienced in prospecting and familiar with the place—searched the entire surface of the ridge, both mounted and on foot, but no additional specimens could be found, nor any spot suggesting that described by the late Mr. Burns.

The failure is explainable by the surface changes that might easily take place in 27 years by reason of erosion, new scrub growth, and the trampling of sheep and cattle. Though the region is arid, local torrential rains or cloudbursts are not infrequent in the mountains, and one such downpour might easily have covered the spot with earth and stones. The growth of a new clump of bushes might also have served to conceal it.

The specimen here described, which seems likely to remain the sole representative of the fall, weighed, when received by the writer, 235 grams, its dimensions being about 5.5 by 4.5 cm. One side is weathered and fissured, resembling the surface of some of the Canyon Diablo "shale balls," the other sides presenting firm fractured surfaces. It is attracted somewhat by a strong magnet, and in places shows the green discoloration of nickel oxide. On one side are a few small shining superficial metallic spots, apparently remnants of taenite lamellae.

A polished surface about 2 by 5 cm was obtained, which shows indistinctly a system of bands slightly under 2.5 mm wide running in one direction, with traces of another set approximately at right angles, indicating that the piece is a pseudomorph of a coarse octahedrite (Fig. 1). The surface revealed a few minute spots of unaltered kamacite, less than half a millimeter in diameter, crossed by Neumann lines (Figs. 2, 3). Numerous rhomboidal crystals of schreibersite (rhabdite) are imbedded in the oxide.

No quantitative analysis has been made, but a qualitative analysis at a commercial laboratory indicated the presence of iron and nickel, with no reaction for chromium, cobalt, or sulphur.

Salina being the town and postoffice nearest to the place of discovery, that name has been chosen for the meteorite here described. It is the fourth meteorite reported from Utah, all of which are irons. It has been given by the writer to the United States National Museum.

ADRIAN, MICHIGAN, JUNE, 1938.

Theoretical Problems of Stellar Absorption Lines

By DONALD H. MENZEL

(Continued from page 79)

(8) *Maxima of Spectral Lines as a Function of Temperature and Pressure.* On the elementary theory of equivalent widths outlined in the previous section, the intensity of a spectral line was made to depend upon knowledge of three parameters, c/v, Z, and X. We shall suppose the

first two quantities to be specified in advance. We have:

$$X = 1.51 \times 10^{-18}(c/v)\,[(\rho/\overline{4l^2-1})\,(Ss/\Sigma s)]\,N_a\,e^{-\chi_{J'}/kT}/b(T)\,, \qquad (1)$$

from (7.23). The quantity in brackets is an atomic parameter, supposedly calculable by the methods of wave mechanics. It is the last factor,

$$N_a\,e^{-\chi_{J'}/kT}/b(T),$$

the number of atoms of the given element, per unit quantum state of the level J', per cm^2 column down to the photosphere, that requires special calculation.

Let n be the total number of atoms of all kinds, per cm^3, at any point in the stellar atmosphere, and let $\overline{m}$ be the average mass of these atoms. Let g be the effective value of surface gravity. Then the increase in pressure, along the distance dr, is

$$dp/dr = -n\overline{m}g, \qquad (2)$$

the well-known equation of hydrostatic equilibrium. We recognize that the total pressure, p, arises partly from atoms and partly from free electrons. If T is the kinetic temperature, and P the electron pressure, we have from Boyle's law,

$$p = (n + n_\epsilon)\,kT, \qquad (3)$$

$$P = n_\epsilon kT, \qquad (4)$$

where $n(\epsilon)$ is the number of free electrons per cm^3. Let θ_a be the abundance, per unit volume, of the given element, and let x_i be the fraction of the element in the significant stage of ionization. Then

$$[N_a/b(T)]\,e^{-\chi_{J'}/kT} = \int_{r_0}^{\infty} [\theta_a n x_i/b(T)]\,e^{-\chi_{J'}/kT}\,dr. \qquad (5)$$

where r_0 denotes the effective level of the photosphere. All of the quantities have been included under the sign of integration because θ_a and T may conceivably be a function of r. Under such conditions the T appearing on the left-hand side would represent some sort of average temperature. For the first approximation we shall assume, in accord with the customary procedure, that θ_a and T are constant; in other words, we assume no stratification or Dalton separation of atoms in the isothermal atmosphere.

From the dissociation formula we have

$$\frac{x_1}{x_0}P = \frac{(2\pi m)^{3/2}(kT)^{5/2}}{h^3}\,\frac{2b_1(T)}{b_0(T)}\,e^{-E_1/kT} = K, \qquad (6)$$

in accord with equations (5.2) and (4). Since, in the absence of second-stage ionization,

$$x_0 + x_1 = 1, \qquad (7)$$

we have

$$x_0 = P/(P+K) \quad \text{and} \quad x_1 = K/(P+K). \qquad (8)$$

Omitting, temporarily, the factors $e^{-\chi_s/kT}$ and $b(T)$, we find for (5),

$$N_{ai} = (\theta_a/\bar{m}g)\int_0^{p_0} x_i\, dp\,, \tag{9}$$

where p is the total pressure at the base of the reversing layer.

Equations of this type have been evaluated by Milne[1] and by Russell,[2] who substitute from equation (8) and then change variables from p to P. Before P can be entirely eliminated, however, we must know the relationship between p and P at every point of the atmosphere, which requires, in turn, knowledge of the chemical composition.

Under certain conditions the integrals may be calculated very simply. The simplest, of course, is that of an atmosphere composed of but a single component, for which

$$p = \frac{1+x_1}{x_1}\,P = \frac{P+2K}{K}\,P \tag{10}$$

and

$$dp = 2\,\frac{P+K}{K}\,dP, \tag{11}$$

by (8). Then, if we let P_0 be the electron pressure at the photosphere, and N_0 and N_1 be the respective numbers of neutral and ionized atoms above the photosphere, equation (9) becomes:

$$N_0 = (1/\bar{m}g)\int_0^{P_0}(2P/K)\,dP = P_0^2/\bar{m}gK \tag{12}$$

and

$$N_1 = (1/\bar{m}g)\int_0^{P_0} 2dP = 2P_0/\bar{m}g\,. \tag{13}$$

We note further that

$$(N_1/N_0)\ (P_0/2) = K. \tag{14}$$

There is an obvious correspondence between (14) and (6), the former dealing with the numbers of atoms above a given layer and the latter with concentrations. This relationship, which was first given by Milne, shows that the simple ionization formula is directly applicable to extended atmospheres when P is replaced by $P_0/2$.

The formulae analogous to (12), (13), and (14), for composite atmospheres, become increasingly complicated as more components are added. Milne has shown, however, that the equation (14) is still a remarkably close approximation to the involved, presumably more accurate mathematical expressions. I say "presumably" because the numerous assumptions involved may lead to errors considerably larger than those resulting from replacing the complicated formulae by the simple type of ionization equation (14).

An enormous simplication, which fortunately introduces no appreci-

[1] *Mon. Not. R.A.S.*, **89**, 17, 1928.
[2] *Ap. J.*, **78**, 239, 1933. *Mt. Wilson Contr.* No. 477.

able error, can be made in (9), by adopting a mean value of x_i. Thus:

$$N_{ai} = (\theta_a/\bar{m}g)\,\bar{x}_i \int_0^{p_0} dp = (\theta_a/\bar{m}g)\,\bar{x}_i\, p_0, \tag{15}$$

where, in the dissociation formula (6), P is to be replaced by $P_0/2$, in accord with (14). In order to make the right-hand side of (15) depend on a single variable, *viz.* P_0, we must express p_0 in terms of the electron pressure.

Disregarding second-stage ionization, we may write for the number of electrons per cm³, at the base of the reversing layer,

$$n(\epsilon) = n \sum_a \theta_a x_{ai} = \beta n, \tag{16}$$

where the index a is now used to distinguish the different elements. β is an abbreviation for the indicated summation. Substituting this result into (3) and (4), we find:

$$p_0 = \frac{1+\beta}{\beta} P_0, \tag{17}$$

and

$$N_{ai} = (\theta_a/\bar{m}g)\,\bar{x}_i \frac{1+\beta}{\beta} P_0. \tag{18}$$

The value of β will depend upon the temperature and the chemical composition as well as upon P_0.

In calculating β, we may obviously lump together all elements of common ionization potential, since the chemical nature of the atoms from which the free electrons originate is of no significance. In his study of the solar atmosphere, Russell[1] concluded that its probable composition, by volume, was: hydrogen 60 parts, helium 2(?) parts, oxygen 2 parts, and metals 1 part. With a few minor changes in the abundance of the elements, as given by Russell, I have grouped the more abundant elements into six classes. The results are shown in Table I, where the mean abundance and excitation potential are given for each group.

The tabulation is merely illustrative. Further investigation[2] will markedly alter the abundance of the He and H groups relative to the metals. As a matter of fact, this ratio may vary from star to star. Fortunately, the theoretical line intensities prove to be not too sensitive to variations in the composition. With the aid of Table I, we now employ equations (16) and (6) to compute values of $\log (1+\beta)P_0/\beta$ as a function of P_0 and T. We note that P_0 and *not* $P_0/2$ is used for P, in equation (6), because the calculations refer specifically to the base of the reversing layer. Instead of T, we employ the convenient parameter

$$z = 5040/T. \tag{19}$$

[1] *Ap. J.*, **70**, 11, 1929.

[2] *Cf.* next section, Table VI, for a revised estimate of abundances.

The calculated values are plotted in Figure 15.

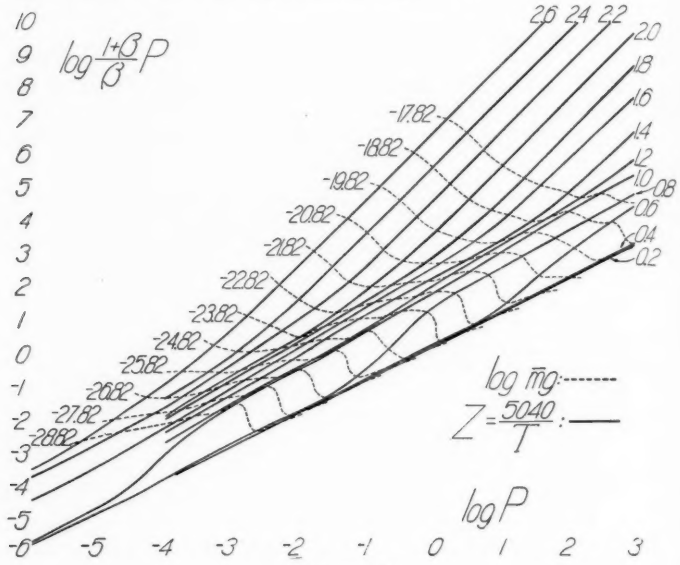

FIGURE 15

The abundances of Table I correspond to a mean atomic weight of 3.5, or $\overline{m} = 5.8 \times 10^{-24}$ grams. For a star of specified surface gravity and temperature parameter z, we need know only one further fact, in order to calculate N_{ai}, from (18), *viz.* P_0. We have pointed out in §(3) that

TABLE I

Element	I.P.	θ_a	$\Sigma\theta_a$	$\overline{\text{I.P.}}$
He	25.5	0.16	0.16	25.5
H	13.54	0.73	0.820	13.5
C	11.2	.004		
N	14.5	.006		
O	13.6	.08		
Mg	7.6	.00560	0.014	7.8
Si	8.1	.00440		
Mn	7.4	.00010		
Fe	7.8	.00360		
Co	7.8	.00008		
Ni	7.6	.00020		
Cu	7.7	.00002		
Al	6.0	.00060	0.002	6.1
Ca	6.1	.00120		
Ti	6.8	.00005		
V	6.8	.00003		
Cr	6.7	.00012		
Na	5.1	.003	0.003	5.1
K	4.3	.001	0.001	4.3
Σ			1.000	

a stellar photosphere is no definite surface but a region wherein the general opacity produces effective obscuration of the underlying layers. Milne has shown that the intensity of the line produced in the real atmosphere will be approximately the same as that produced in a fictitious transparent atmosphere backed by a radiating surface, if we take N_{at} equal to the number of atoms down to optical depth $\tau = \frac{1}{3}$ in the real atmosphere.

We are required to evaluate the electron pressure at the level where the general opacity builds up to an optical depth $\frac{1}{3}$. Possible sources of opacity have been indicated in section (2). Bound-free transitions probably contribute appreciably to the opacity for certain types of stars. Let N_n be the number of atoms per cm^3 in quantum level n of a hydrogenic atom. Then

$$d\tau(\nu) = \Sigma N_n a(\nu)\, dr, \tag{20}$$

where dr is, as previously, an element of the stellar radius. The summation is to be carried over all values of n whose series limits lie to the red of the frequency considered, *i.e.*,

$$\nu \geqslant RZ^2/n_0^2. \tag{21}$$

We now substitute (2.8), (5.11), and (5.4) into (20), whence:

$$d\tau(\nu) = N_t N(\epsilon)\, \frac{h^3}{(2\pi mkT)^{3/2}}\, \frac{\pi\epsilon^2}{mc}\, \frac{2^4}{3^{3/2}\pi}\, \frac{R^2Z^4}{\nu^3}\, dr \sum_{n_0}^{\infty} \frac{e^{hRZ^2/n^2kT}}{n^3}, \tag{22}$$

where we have set $b = 1$, assuming that thermodynamic equilibrium is a fair approximation for opacity arising from ionization of metallic atoms in the higher quantum levels. The successive levels, with non-zero quantum defect, may be regarded as overlapping to form an effective continuum of absorption band edges. Hence, we replace the summation in (22) by an integral sign, multiply by dn and regard n_0 as a continuous index defined by

$$\nu = RZ^2/n_0^2, \tag{23}$$

instead of by (21). The result of the integration is

$$\begin{aligned} d\tau(\nu) = N_t N(\epsilon)\, \frac{h^3}{(2\pi mkT)^{3/2}}\, \frac{\pi\epsilon^2}{mc}\, \frac{2^4}{3^{3/2}\pi}\, \frac{RZ^2}{\nu^3}\, (kT/h)\, (e^{h\nu/kT} - 1)\, dr \\ = 2.02 \times 10^{40} \frac{P^2}{\nu^3 T^{6/2}}\, (e^{h\nu/kT} - 1)\, dr. \end{aligned} \tag{24}$$

A detailed investigation shows that the effect of the free-free transitions and the stimulated emissions just cancel. Let

$$\begin{aligned} \int P^3 dr = (1/\bar{m}g) \int_0^{p_0} (P^2/n)\, dp = (kT/\bar{m}g) \int_0^{p_0} \beta P\, dp \\ \sim (kT/\bar{m}g)\, \bar{\beta}\, (P_0/2) \int_0^{p_0} dp \sim (kT/\bar{m}g)\, (P_0^2/2)\, (1+\beta), \end{aligned} \tag{25}$$

from (2), (4), (16), and (17). Therefore

$$\tau = \frac{1.34\times10^{24}}{\bar{m}g}\,\frac{P_0^2}{T^{5/2}}\,\frac{(e^{h\nu/kT}-1)}{\nu^3}\,(1+\beta) = \tfrac{1}{3}. \tag{26}$$

For given temperature, effective surface gravity, and mean atomic weight, we can evaluate the photospheric electron pressure directly from this equation. The solution of (26) for selected values of $\bar{m}g$ is plotted in Figure 16, as a function of the temperature parameter z, equation

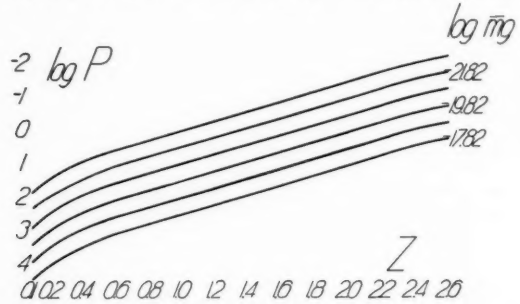

FIGURE 16

(19). The calculations are for the adopted frequency $\nu = 6\times10^{14}$, corresponding to a wave-length of 5000 A.

The values of P_0, for the given z and $\bar{m}g$, have been transferred to Figure 15, where the dotted lines refer to a given $\bar{m}g$. The values of $\log p_0 = \log P_0(1+\beta)/\beta$, for given $\bar{m}g$, are shown in Figure 17, as

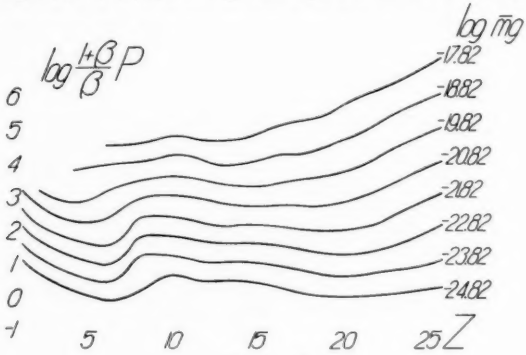

FIGURE 17

a function of z. This diagram, therefore, furnishes the value of the important and more complicated factor of equation (18).

Accordingly, for a star of predetermined chemical composition and

fixed physical parameters $\bar{m}g$ and z, the numbers of active atoms effective in producing a given absorption line,

$$N_{eff} = \frac{N_a}{b(T)} e^{-\chi_J/kT} f \tag{27}$$

can be computed directly.

Russell[1] has computed the values of N_{eff} for the giant and dwarf stars, on a theory of atmospheric opacity similar to that explained herein. The chief point of disagreement is in the matter of the opacity associated with free-free transitions: Russell used Sugiura's value, which gives too high an opacity, especially in the hottest stars of types A0 and earlier. A check calculation, wherein the more accurate but much more complicated formulae of Russell were used instead of equation (15), showed that no appreciable errors were introduced by the approximation.

The results for the giant sequence are shown in Figure 18, wherein

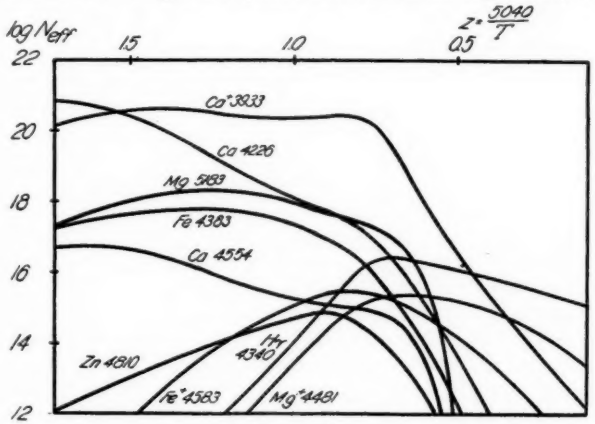

FIGURE 18

log N_{eff} is plotted against z. The values of $\bar{m}g$ adopted are those given by Russell as appropriate for giant stars of given temperature. The results have been plotted on an absolute scale.

The curves, which show the rise and fall of N_{eff} along the sequence, have generally been regarded as indicating the analogous trend of the line intensities. A few obvious difficulties arise, even with this simple qualitative interpretation. For example, the theoretical maximum for Hγ comes at $z = 0.72$, *i.e.*, for $T = 7000°$. This value of T corresponds more nearly to an F5 star than to an A0 or A2 star where the hydrogen lines are observed to have maximum intensity.

It is tempting to suggest that the displaced maximum may be due to Stark effect, but the behavior of absorption beyond the series limits

[1] *Ap. J.*, **78**, 246, 1933; *Mt. Wilson Contr.* 477.

shows that this explanation cannot be accepted. The lower temperature may possibly be a sort of boundary temperature, analogous to the value of 4500° found for the sun. The chief encouraging factor is that theoretical maxima for Hγ and 4481 of Mg II come at about the same value of z, even if the temperature is unexpectedly low.

There are further checks to be made, however, on the quantitative side. We may return to equation (1) of this section and calculate the value of X. Miss Carol Nottage, who has carried on an extensive study of the theoretical problem of line intensities here at Harvard, has kindly prepared the table given as Table II. The values of X were

TABLE II

Element	λ	X computed $T = 4500°$	X computed $T = 5740°$	X observed (Sun)
Fe	4045.8	+6.41	+5.82	+4.47
Mg	5184	+6.23	+5.78	+4.35
Mg+	4481	−0.01	+2.59	+0.75
Ti	4533	+4.46	+3.52	+1.90
Ti+	4300	+4.83	+5.27	+2.35
Si	5708	+2.30	+2.81	+0.76
Si+	6347	−2.50	+0.70	+0.27
Sc+	4341	+4.27	+4.58	+1.72
Ca	4227	+9.02	+7.68	+4.46
Na	5890	+6.62	+5.54	+3.77
Hγ	4340	−1.21	+1.30	+5.25

computed on the assumption that $\rho/(4l^2 - 1) = 1$, which is probably not far from the true wave-mechanical value for first series members. Slightly higher values may be necessary, but smaller values are expected only for high members of a series.

The discrepancies between the theoretical and observed values are probably beyond the range allowed even by "astrophysical accuracy." Two effects are observed. One discrepancy can be removed only if the solar atmosphere is appreciably more opaque than theory indicates, thereby cutting down the total number of atoms. The second is the well-known tendency of the hydrogen lines and other lines of high excitation potential to appear too strong. This peculiarity is by no means confined to the sun. The strength of hydrogen absorption in late-type stars is a familiar but unexplained anomaly.

Miss Nottage has attempted to find a suitable chemical composition that would bring the computed and theoretical values of X into agreement. There appears to be no possibility of removing the discrepancy without first assuming a departure from the conditions of thermodynamic equilibrium. The difficulty lies in finding a physical basis for introducing such a departure into the theory.

In view of the numerous difficulties, we should regard curves like those of Figure 18 as only qualitative. The intriguing complexities of turbulence and of atmospheres partially supported by radiation pressure, with the resultant influence on the value of X and the line intensity, make the problem of predicting line intensities very difficult.

(9) *Chemical Composition.* The problem of determining the relative abundance of the various elements is intimately bound up with questions discussed in §§ (7) and (8). The procedure for the sun, for which fairly extensive measures of equivalent widths exist, is plain. The fundamental equation is (7.25), which is diagrammed in Figure 13. The slope of the line determines the effective excitation temperature, and the Y intercept, for $\chi_{J'} = 0$, determines L. Then the number of atoms of a given element, in a given state of ionization, per cm² column above the photosphere, is, from (7.25),

$$\log N_a = L + 17.82 - \log (c/v) + \log b(T) - \log \rho/(4l^2 - 1). \qquad (1)$$

Dr. Goldberg and I are attempting an analysis of the solar atmosphere by the above method. The results are not yet ready for publication, but the relative abundances derived for the metals will probably not differ significantly from those determined by Russell.[1] Russell's method differs from ours in the data employed (Rowland intensities) and the method of analysis. But the principles of atomic theory used in both investigations are basically similar.

At present all determinations of abundances are subject to error because of uncertainties in the value of the radial quantum integral, ρ. Knowledge of this quantity can come only from wave-mechanical calculations or from laboratory experiment. The latter method is to be preferred for the complex atoms.

Despite the uncertainty in ρ, however, we can obtain approximate values of the relative abundances of certain groups of elements. The metals of the first long period, Ti, V, Cr, Mn, etc., possess related transition arrays, for which the jumping electron makes the same sort of orbital transition, *e.g.*, 3d - 4p. As a first approximation we may assume that the ρ's are constant for such arrays. There will, of course, be a systematic trend of ρ along the periodic table, but the errors in comparing the abundances of two neighboring atoms, or of an atom and its ion, are at least partially eliminated by this assumption, when no further data concerning ρ are available.

The most accurate solar abundances are determined for those elements where the observations include resonance lines or lines that arise from levels within a couple of volts of the ground level. Inaccuracies of observation and in the value of the excitation temperature introduce no serious errors. Under this classification come practically all of the neutral metals, and many of the ionized metals.

Atoms that fall outside of this classification are H, He, He^+, C, N, O, Ne, Mg^+, and Si^+. Several of the atoms listed above possess no observed Fraunhofer lines; but for all of them the excitation potentials of all the lines that lie in the observable region are extremely high. Except for Si^+, the energy levels involved are nearer the ground level of the next higher

[1] *Ap. J.*, **70**, 11, 1929.

ionization stage than the ground level of the stage responsible for the line.

In order to calculate L, the term $5040\,\chi_{J'}/T$ must be added to the observed Y. Hence, since $\chi_{J'}$ is large, errors in T will lead to large errors in L. The difficulty is best illustrated by considering the well-known example of the Balmer series of hydrogen.

Measures of the equivalent widths,* especially of the higher series members, indicate that N_2, the number of 2-quantum H atoms, per cm² column above the photosphere, is about 5×10^{15}. The partial pressure p_2 of 2-quantum H atoms, *i.e.*, the weight of these atoms, is

$$p_2 = N_2 m_1 g = n_2 kT, \tag{2}$$

where m_1 is the mass of a hydrogen atom, g the effective value of solar gravity, and n_2 the number of 2-quantum H atoms per cm³ at the base of the layer. The second part of the equation is from Boyle's law, as in (8.3). Setting $m_1 = 1.66 \times 10^{-24}$, $g = 2.73 \times 10^4$, $k = 1.37 \times 10^{-16}$, and $T = 4500°$, we have

$$n_2 = 4 \times 10^8 \text{ atoms / cm}^3. \tag{3}$$

Applying the Boltzmann correction for the various temperatures, as indicated, we find for the number of 1-quantum atoms n_1, and for p_1, the pressure of 1-quantum atoms, the respective values of Table III.

TABLE III

$T = 4{,}500°$	$n_1 \sim 3 \times 10^{19}$	$p_1 \sim 2 \times 10^7$ dyne = 20 atmos.
$T = 6{,}000°$	$n_1 \sim 4 \times 10^{18}$	$p_1 \sim 3 \times 10^6$ dyne = 3×10^{-2} atmos.
$T = 10{,}000°$	$n_1 \sim 1 \times 10^{15}$	$p_1 \sim$ 10 dyne = 10^{-5} atmos.

The large error introduced by uncertainty in the temperature, as well as the necessity of postulating an excitation temperature, for H, well in excess of 4500°, are shown by the above equations.

The uncertainty in calculating the number of ionized hydrogen atoms is much less. Assuming thermodynamic equilibrium, *i.e.*, taking $b_2 = 1$, we employ equations (3) and (5.11) to evaluate n_i. For $n(\epsilon)$, we make use of the photospheric electron pressure, 20 dynes, estimated from the observed ionization of the metals. Then, by (8.4), we have

$$n(\epsilon) \sim 2 \times 10^{13}. \tag{4}$$

Equation (5.11) becomes

$$\log n_i = \log n_2 - \log n(\epsilon) + 14.8 + (3 \log T)/2 - \frac{5040 \times 3.39}{T}$$

$$= 10.1 + (3 \log T)/2 - \frac{17{,}100}{T}. \tag{5}$$

The results are given in Table IV.

TABLE IV

$T = 4{,}500°$	$n_i = 5 \times 10^{11}$
$T = 6{,}000°$	$n_i = 8 \times 10^{12}$
$T = 10{,}000°$	$n_i = 2 \times 10^{14}$

*Unsöld, *Zeit. für Phys.*, **59**, 353, 1930; cf. also Menzel, *Publ. Lick Obs.*, **17**, 1931.

The approximate equality of the number of hydrogen ions and free electrons per unit volume is evident. As a matter of fact, since n_i cannot exceed $n(\epsilon)$, we see that $T \leqq 6600°$. For this temperature all of the electrons are attributed to hydrogen.

TABLE V

	$T \leqq 6600°$
$n_1 \leqq n(\epsilon)$	$= 2 \times 10^{13}$
n_1	$\geqq 6 \times 10^{15}$
p_1	$\geqq 5 \times 10^3$ dyne $= 5 \times 10^{-3}$ atmos.

Further conclusions are given in Table V. The values of n_1 and p_1, obtained by an extrapolation of the Boltzmann formula, are to be regarded as minimum values. The effects of deviation from thermodynamic equilibrium will tend to increase the tabulated values.

We now return to consideration of the problem of the opacity of the solar atmosphere. We have already noted, in the previous section, that interaction of electrons and metallic ions fail by a factor of 100 of accounting for the opacity. Nor can we appeal to the free electrons or the neutral hydrogen atoms. Equation (8.22), which is to be summed from $n_0 = 3$ to ∞, falls far short of yielding the requisite opacity. There are two possible additional sources of opacity. The electrons, in free-free transitions with neutral hydrogen atoms and in bound-free transitions with negative hydrogen ions, must be considered.

Dr. Wildt has kindly called my attention to the fact that hydrogen atoms possess an affinity for free electrons. The ionization potential of the negative ion has been computed by Hylleraas[1] and Bethe.[2] Jen[3] has calculated the absorption coefficient of these ions. For wave-length 5000 A, he finds the value

$$\alpha(\nu) \sim 2.3 \times 10^{-17} \text{ cm}^2, \tag{6}$$

per negative ion. The opacity arising from the free-free transitions in neutral hydrogen has been discussed by Menzel and Pekeris,[4] who find

$$\alpha(\nu) = 1.5 \times 10^{-26} P, \tag{7}$$

for the same wave-length, per neutral hydrogen atom. P is the electron pressure, in dynes.

For an atmosphere consisting chiefly of hydrogen, the optical depth, down to a layer where the total pressure is p_0 and the electron pressure P_0, is easily found to be

$$\tau = \frac{P_0 p_0}{2m_1 g}\left(\frac{2.3 \times 10^{-17}}{K} + 1.5 \times 10^{-26}\right). \tag{8}$$

The dissociation constant for the negative ions is given by (8.6), with

$$E_1 = 0.715 \text{ volts}, \tag{9}$$

[1] *Zeit. für Phys.*, **60**, 624, 1930.
[2] *Zeit. für Phys.*, **77**, 815, 1929.
[3] *Phys. Rev.*, **43**, 540, 1933.
[4] *Mon. Not. R.A.S.*, **96**, 77, 1935.

as given by Hylleras. Also

$$b_0(T) = 1 \quad \text{and} \quad b_1(T) = 2. \tag{10}$$

The value of K is fairly insensitive to temperature. For $T = 6000°$, we find

$$K = 9.1 \times 10^5. \tag{11}$$

For $T = 4500°$,

$$K = 2.9 \times 10^5. \tag{12}$$

Setting $\tau = \frac{1}{3}$ in (8), and introducing numerical values, we find that the pressure of neutral hydrogen at the base of the reversing layer lies somewhere in the range from 2×10^4 to 6×10^4 dynes. This pressure is not far from that produced in an atmosphere in thermodynamic equilibrium at 6000°, as shown in Table III.

This result is sufficiently close to the minimum value quoted in Table V to lend weight to the assumption that the opacity of the solar atmosphere is due almost entirely to hydrogen affinity for free electrons. It appears to be the only process capable of giving the correct order of opacity. In the hotter stars, of course, the ordinary bound-free transitions from the neutral hydrogen atom will predominate over those from the negative ion. Although the total pressure is somewhat higher than the value customarily given, it is still low enough, less than 0.06 atmospheres, that no marked pressure effects should be found.

These results are equivalent to a marked increase in the ratio of hydrogen to metallic atoms. The abundances of the latter are to be decreased, in Table I, by a factor that I set provisionally at 100. The changed values of the respective $\Sigma\theta_a$'s are given in Table VI.

TABLE VI

Element	$\Sigma\theta_a$
He	0.16000
H, etc.	0.83980
Mg, etc.	0.00014
Al, etc.	0.00002
Na	0.00003
K	0.00001
Σ	1.00000

These figures would imply that the abundance of hydrogen is about 4000 times that of all the metals combined. It is interesting to note that Pannekoek,[1] from an entirely independent analysis, arrived at a ratio of 5000 to 1, although he arbitrarily reduced it to 1000 to 1. For the present the question raised earlier in this section, regarding the origin of the electrons, will have to remain unsettled. The indications, however, are that, after all, the majority of electrons can be attributed to the metal ions. The metals are more than fifty per cent ionized, and the observed ratio of hydrogen pressure to the electron pressure, at the base of the reversing layer, *viz.*, $6 \times 10^4 : 20$, is about 3000, in agreement with the hypothesis that the electrons come chiefly from the metals.

The next most important composition parameter, the relative abund-

[1] *Publ. of the Astron. Instit. of the Univ. of Amsterdam*, No. 4, p. 10, 1935.

ance of H and O, is more difficult to determine. The most important group of O I lines, in the solar spectrum, is that at 7770 A, $3s^5S - 3p^5P$. The equivalent widths of these lines have been measured by Allen.[1] Estimating log X from the curve of growth, and reducing the observational data according to equation (7.25), we finally obtain for the total number of oxygen atoms per cm^2,

$$N_a \sim 3 \times 10^{20}. \tag{13}$$

This value is subject to considerable uncertainty. In the calculation we have assumed

$$\rho/(4l^2 - 1) = 1 \tag{14}$$

and

$$T = 6000°. \tag{15}$$

The excitation temperature thus adopted is in accord with that employed for the hydrogen calculations. Hydrogen and oxygen possess identical ionization potentials.

Analogous to (13) and consistent with a pressure of 6×10^4 dynes, we have

$$N_H \sim 10^{24}. \tag{16}$$

The abundance of oxygen, therefore, is comparable with that of the metals. The abundances of carbon and nitrogen are to be similarly reduced, from their values given in Table I.

The most uncertain factor remaining is the abundance of helium. The value quoted in Table I is a very provisional estimate based on studies of the chromosphere. Its magnitude depends so markedly on the enormous Boltzmann correction that little weight is attached to the quoted value. The chief argument for its general correctness, apart from the sun, is that it leads to a satisfactory prediction of the order of magnitude of the intensities of helium lines in early-type stars. The helium abundance should be more accurately determined from B and O spectra, because the Boltzmann correction is much less. As far as the sun is concerned, any small change in the correction will make helium either negligible or predominant.

The chief conclusion of the present section, then, is an affirmation of the view that hydrogen is the principal constituent of stellar atmospheres. In fact we may say that, apart from helium whose abundance is as yet unknown, the visible portion of the universe consists of chemically pure—but not "spectroscopically pure"—hydrogen.

(10) *Miscellaneous Difficulties and Outstanding Problems.* The theory of stellar absorption lines, after primary success in accounting for curve-of-growth phenomena, has led to disappointment in the matter of variation along the spectral sequence. I have shown how the observational data for the sun, with additional assumptions involving super-excitation, particularly of helium, can be fitted into the picture. But the correction

[1] *Mon. Not. R.A.S.*, **96**, 843, 1936.

for failure of the solar atmosphere to conform to thermodynamic equilibrium rests entirely on observation. We see further indications of an analogous effect in the spectra of late-type stars, where the Balmer absorption lines are exceptionally strong.

Some years ago astrophysicists discussed "departure from thermodynamic equilibrium" as an effect resulting from dilution of radiation, *i.e.,* from the fact that an atom high in a stellar atmosphere is exposed to radiation over a hemisphere instead of over a sphere, as for a "hohlraum." Investigation of the effect has shown that "dilution" has only a secondary influence on the excitation, and that quality of the radiation is the primary factor governing the excitation. This statement applies even to rarefied nebulae, excited by extremely diluted radiation. Hence, when certain atoms like hydrogen and helium exhibit superexcitation, we conclude that they merely reflect the character of the radiation. The evidence points toward an intensity of solar ultra-violet radiation far in excess of that from a black body at 6000°.

The greatest problem in the interpretation of absorption lines, it thus appears, is more directly a question of transfer in the continuum than in the lines. At present, no simple solution is evident. Various possibilities, none of which seems to offer much hope of removing the difficulties, must be considered. The most obvious, a "window" that allows the ultra-violet radiation to shine through, meets with an obvious objection. The solar atmosphere should actually be most opaque in the region where the window is most necessary, just beyond the limit of the Lyman series.

An appreciable temperature gradient would be of some value; as indicated in (8.5) the expression for the line intensity would include an integration over the temperature as well as over the pressure. This effect may be of importance in certain super-giant stars, whose very extensive atmospheres are conducive to the formation of high temperature gradients.

Gradients of this character may explain such well-known anomalies as the presence of emission lines of hydrogen in the spectra of the long-period variables. The suggestions made by Wurm, relative to molecular dissociation as a possible source of emission lines in the long-period variables, meet with one difficulty. If a hydrogen-containing molecule is to dissociate into a normal atom and an excited hydrogen atom, it is obvious that the total energy required to repeat the operation is at least as great as that required for Balmer excitation. In consequence, dissociation does not explain the bright lines, though it does provide a mechanism for their origin, if sufficient energy is forthcoming. I should prefer to rely on cyclic processes, analogous to those operative in gaseous nebulae. The emission, in long-period variables, is obviously a low-level phenomenon, as shown by the absence of Hϵ and other higher series members, all of them covered up by overlying absorption. The hydrogen lines are excited in the hotter levels, where ample ultra-violet radiation is available.

In the solar atmosphere, as I have shown, the anomaly occurs not at low but at high levels. The observed Fraunhofer infra-red helium line is almost certainly of chromospheric origin. The implied temperature gradient, if the term can be used to describe so exceptional a physical condition, is *negative*. In bringing the chromosphere into the picture, I feel that I am not "making a mountain out of a mole-hill." In giant and super-giant stars, the chromosphere is probably much deeper and may be the source of Fraunhofer absorption. The evidence of ζ Aurigae on this point is very suggestive. But if this picture is correct, in addition to the uncertain excitation correction at least two and possibly three further complications occur.

One of these complications we have already referred to, *viz.*, "turbulence," which, if interpreted along the lines proposed by Struve, becomes a chromospheric type of phenomenon. The second factor is the value of g, which enters the problem not as the true value of gravity but as a parameter characterizing the density gradient of the stellar atmosphere. Levitation of the chromosphere will reduce the value of g. Hence, in interpreting the spectra of stars, we shall have to determine this additional parameter from the observations, until a satisfactory theory both of turbulence and chromospheric support is evolved. Not improbably the two effects will be correlated.

The third complication is one that has also been observed in the chromosphere: a differential separation of the various atmospheric constituents. Separation of this character indubitably occurs in the chromosphere, where, despite the apparently low value of g, the separation appears to be correlated with the atomic weight. Ba^+ possesses a steeper density gradient than Sr^+. Similarly, Sr^+ is more concentrated in the lower levels than Ca^+, Zr^+ than Ti^+, and the heavy rare-earths show the steepest gradients of all.

The general effect of such a separation is obvious. It must certainly be included in theoretical developments like those of § (8). One might expect lines of heavier atoms to be more prominent in the spectra of dwarf stars, but the relative intensities depend also upon the general opacity so that no quantitative deductions are possible.

There is one piece of observational evidence that points to gravitational separation rather than to actual differences of chemical composition, as the source of spectral differences. In the spectra of long-period variables of S type, *e.g.*, χ Cygni, we frequently find an alternation between the M and S characteristics. Since the star can scarcely be altering its ultimate chemical composition during the variation, it is tempting to suggest that the spectral changes may be due to the gravitational separation, with different layers responsible for the spectral variations. Possibly the entire M-S differentiation is attributable to this effect.

Whether the other anomalous groups of stars, the Sr^+, the Si^+, the rare-earth, the oxygen, and the carbon varieties, can be similarly explained is in doubt at the present. If the full differential gravitational

effect were operative, the theoretical separation would be many times larger than necessary to explain the observed phenomena. In the solar atmosphere, for example, the relative concentration of elements as similar in atomic weight as O and C would be altered by a factor of e, in only fifty kilometers. The mere fact, however, that the rare-earths and even lead are represented in the Fraunhofer spectrum shows that some stirring action opposing the settling processes is at work. At this point theories of stellar interiors can contribute significantly.

Consideration of the numerous peculiarities of stellar spectra leads me to conclude that there is evidence for true differences in chemical abundances. As a matter of fact one may argue that even those resulting from gravitational separation are none the less real abundance differences.

I consider as particularly significant the spectra of novae. I see no way of escaping the conclusion that neon is probably more abundant in Nova Persei (1900) than in most celestial bodies. From the time the nebular spectrum first appeared, down to the present day, over an enormous change in excitation conditions, the lines of neon have dominated the spectrum. Sulphur is similarly extremely intense in the spectrum of Nova Pictoris (1925).

The carbon stars are another example that probably requires fundamental differences in chemical composition for explanation. Certain Wolf-Rayet stars, which, as is well known, show the lines of He^+ (Pickering series) in emission but no sign of the Balmer lines of hydrogen, are another undoubted example of chemical differences. In this example it has been suggested that the hydrogen may have been eliminated by radiation pressure. If this explanation is true, it is an extreme case of the separation effect.

Further difficulties and problems of stellar spectra could be listed almost without end. Here we have scarcely touched upon the important group of hot stars with distended envelopes—objects intermediate between normal stars and planetary nebulae. But to multiply the difficulties would serve no useful purpose. The chief conclusion is that the theoretical interpretation of stellar spectra is, for the present, a problem for each individual stellar spectrum. Removal of the restrictions, which may eventually lead to a quantitative prediction of the absolute-magnitude effects and variation along the spectral sequence, will probably have to wait for the detailed analysis, *via* curves of growth, of numerous varieties of stellar spectra.

Acknowledgments. I wish to express my appreciation to Dr. C. H. Gingrich, editor of POPULAR ASTRONOMY, for assistance in re-writing the equations in a form suitable for publication in this journal. I also wish to pay tribute to the skill and patience of the compositors, who, though unfamiliar with technical mathematics, have so efficiently set the type for this paper.

HARVARD COLLEGE OBSERVATORY.

Program for the Dedication of the McDonald Observatory

The dedication of the McDonald Observatory of the University of Texas, which is being operated jointly by the University of Chicago and the University of Texas, has been scheduled for Friday afternoon, May 5, as a part of the annual meeting of the Southwestern Division of the American Association for the Advancement of Science, which will be held this year at Alpine, Texas, about forty-two miles from the Observatory. Under the auspices of the Warner & Swasey Company and the Observatory, an astronomical symposium is to be held, under the general title "Galactic and Extragalactic Structure." Astronomers are invited to attend the dedication and the symposium, and are requested to make hotel reservations by writing to the Observatory, Fort Davis, Texas. The program of the symposium and of the dedication is as follows:

THURSDAY, MAY 4

Arrival at Alpine, Texas

Afternoon: Regular session of the Southwestern Division, A.A.A.S. at Sul Ross State Teachers College. Presentation of contributed papers

Evening: Powell lecture under the auspices of the A.A.A.S.
"Physics Views the Future," Dr. A. H. Compton, University of Chicago

FRIDAY, MAY 5

9:30 A.M.-12:00

Astronomical Symposium and A.A.A.S at the McDonald Observatory

Presiding: Professor Henry Norris Russell, Princeton University Observatory

"Recent Advances in Astronomy," Professor Harlow Shapley, Harvard College Observatory
"Astronomy in Mexico," Dr. J. Gallo, National Observatory of Mexico
"The 82-inch Telescope," Dr. J. S. Plaskett, Director Emeritus of Dominion Astrophysical Observatory

12:30-2:00 P.M.

Chuck Wagon dinner at the Observatory by invitation of the Warner & Swasey Company

3:00 P.M.

Dedication of the McDonald Observatory

Tender of completed Observatory to the Director by President P. E. Bliss of the Warner & Swasey Company
Acceptance of completed Observatory by Professor Otto Struve, McDonald Observatory
"The Coöperative Enterprise," President Robert Maynard Hutchins of the University of Chicago
Acceptance for the University of Texas by a member of the Board of Regents
"Some Features of the New Mirror," Dr. J. S. Plaskett, Director Emeritus of the Dominion Astrophysical Observatory
"The First of the Sciences," Professor Arthur H. Compton, University of Chicago
Dedication of the Observatory, by President J. W. Calhoun of the University of Texas

SATURDAY, MAY 6

Symposium on "Galactic Structure"

9:30 A.M.-12:00

Presiding: Professor S. A. Mitchell, McCormick Observatory

"Present Problems," Dr. J. H. Oort, Leiden Observatory
"Star Clusters," Dr. R. J. Trumpler, University of California

2:30-5:30 P.M.

Presiding: Professor H. G. Gale, University of Chicago

"Interstellar Matter," Dr. Otto Struve, Yerkes Observatory
"Star Counts," Dr. Bart J. Bok, Harvard College Observatory
"Galactic Light," Dr. C. T. Elvey, McDonald Observatory
"Under-Luminous Stars," Dr. G. P. Kuiper, Yerkes Observatory

8:00 P.M.

Presiding: Dr. Edwin Hubble, Mount Wilson Observatory

"Cosmological Theories," Dr. E. A. Milne, Oxford University

SUNDAY, MAY 7

Symposium on "Galactic and Extragalactic Structure"

9:30 A.M.-12:00

Presiding: Professor E. F. Carpenter, Steward Observatory

"Photometric Problems," Dr. Walter Baade, Mount Wilson Observatory
"Space Distribution of Extragalactic Nebulae," Professor Harlow Shapley, Harvard College Observatory

2:30-5:30 P.M.

Presiding: Dr. W. S. Adams, Mount Wilson Observatory

"Stellar Spectra and Colors," Dr. Cecilia Payne Gaposchkin, Harvard College Observatory
"Stellar Colors and Luminosities," Dr. W. W. Morgan, Yerkes Observatory
"Theoretical Interpretation of Spiral Structure," Dr. Bertil Lindblad, Stockholm Observatory and Morrison Research Associate at the Lick Observatory
"Star Streaming and Dynamics of Stellar Systems," Dr. S. Chandrasekhar, Yerkes Observatory

8:00 P.M.

Presiding: Dr. Arthur H. Compton, University of Chicago

"Structural Features of Extragalactic Nebulae," Dr. Edwin Hubble, Mount Wilson Observatory

MONDAY, MAY 8

9:30 A.M.-12:00

Presiding: Dr. W. H. Wright, Lick Observatory

"Space Reddening in the Galaxy," Dr. Joel Stebbins, Washburn Observatory
"Stellar Masses," Professor Henry Norris Russell, Princeton University Observatory

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MEETING OF THE SOUTHWESTERN DIVISION OF THE A.A.A.S.

The Southwestern Division of the American Association for the Advancement of Science will hold its annual meeting at Alpine, Texas, next May 2 to 5, inclusive, immediately preceding the dedication cere-

mony and astronomical symposium of May 5 to 8 at the McDonald Observatory.

On Thursday morning and afternoon the sessions of the Division's Section on Physical Sciences will be reserved for astronomical papers. Contributions to this program are invited from all observatories. Titles should be sent to Dr. C. T. Elvey, McDonald Observatory, Fort Davis, Texas, before April 1.

Planet Notes for April, 1939

By R. S. ZUG

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. The positions of the sun for April 1 and April 30, respectively, are: $\alpha = 0^h\,38^m1$, $\delta = +4°\,1'6$; $\alpha = 2^h\,25^m5$, $\delta = +14°\,25'5$.

The sun is in the constellation Pisces until April 18, when it enters Aries. Values for the equation of time are as follows:

Date 1939	Equation of Time (Mean - Apparent) m s	Date 1939	Equation of Time (Mean - Apparent) m s
Apr. 1	+ 4 19	Apr. 17	— 0 7
5	+ 3 7	21	— 1 1
9	+ 1 58	25	— 1 49
13	+ 0 53	29	— 2 29

Moon. Phenomena of the moon will occur as follows:

		h	m
Full Moon	April 4	4	18
Last Quarter	11	16	11
New Moon	19	16	35
First Quarter	26	18	25
Perigee	1	13	
Apogee	13	9	
Perigee	28	10	

Eclipses. On April 19, an annular eclipse of the sun will be visible along the southern coast of Alaska. The eclipse will be seen as partial over practically the entire area of the United States. The exception is Florida south of latitude 30°, which is out of the eclipse area. In the eastern part of the United States the partial eclipse lasts from about 11:00 A.M. to 1:00 P.M., Eastern Standard Time. In the central states the corresponding interval is from about 9:30 A.M. to 11:30 A.M., Central Standard Time. In western United States the eclipse lasts from about 6:45 A.M. to 9:00 A.M., Pacific Standard Time. For more detailed information concerning the eclipse at any particular region, and for an eclipse map, the reader may refer to the article, "Planetary Phenomena in 1939" which appeared in the January, 1939, issue of POPULAR ASTRONOMY, p. 29.

Mercury. Mercury is poorly placed for observation during April. Inferior conjunction occurs April 3. Thereafter the planet is a morning star, and by the end of the month is near greatest western elongation. However, it will be inconspicuously situated at a low altitude in the morning sky.

Venus. Venus is still a fine morning object, but rapidly receding from the earth. The distances of the planet from the earth on April 1 and May 1, respectively, will be 104,000,000 and 122,000,000 miles. The magnitude of the planet will be —3.6 on April 1, and —3.4 on May 1. The planet will be about 14″ in angular diameter during April, and gibbous in phase. On April 22 and 23, Venus will be situated about a half degree south of Jupiter in the morning sky.

Mars. Mars is a morning star in the constellation Capricornus. The brightness of the planet is increasing, the stellar magnitude varying from +0.4 on April 1 to —0.2 on May 1. On the latter date the planet will be 76,700,000 miles from the earth.

Jupiter. The planet Jupiter is now to be seen in the morning sky. It is advancing eastward along the ecliptic, and by the end of the month will be but 3° west of the vernal equinox. The magnitude of the planet is —1.6.

Saturn. Saturn will be in conjunction with the sun on April 11.

Uranus. Uranus is still in the evening sky, but too near the sun for satisfactory observation. The positions of the planet for April 1 and April 30, respectively, are: $\alpha = 2^h\,53^m.4$, $\delta = +16°\,14'.0$; $\alpha = 2^h\,59^m.7$, $\delta = +16°\,41'.3$.

Neptune. Neptune should be a fine object for evening observation during April. On April 2, $12^h.2$, the planet will be situated 2′ 34″ north of the 8.8 magn. star, B.D.+4°2492, a circumstance that should enable amateurs and others to locate the planet without much difficulty. It also provides opportunity for comparing the disk of Neptune with a star, in the same field of view, with a magnification of 150 or 200. The course of the planet near this star can be studied by means of the chart appearing in POPULAR ASTRONOMY for January, 1939, p. 36. The chart is arranged for use with an inverting telescope.

Occultation Predictions

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′.

Date 1939	Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
Apr. 1	14 Sex	6.3	6 12.9	—0.7	—1.5	108	7 13.1	—0.3	—1.8	298
5	86 Vir	5.8	4 4.1	..	..	48	4 34.7	..	..	1
8	123 B.Sco	6.5	9 12.1	—2.1	—1.9	142	10 6.2	—1.6	+0.7	222
23	*i* Tau	5.1	0 58.0	—0.1	—1.6	110	1 52.1	0.0	—1.0	257
30	431 B.Leo	6.2	5 58.0	—0.8	—1.2	88	6 55.2	—0.3	—2.1	315

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′.

Apr.	1	14	Sex	6.3	6	0.9	—1.0	—1.9	131	7	6.3	—1.0	—1.5	281
	5	86	Vir	5.8	3	24.9	—1.1	+1.2	90	4	28.1	—0.8	—0.5	318
	8	123	B.Sco	6.5	8	44.9	..	..	160	9	25.0	..	..	215
	11	ρ	Sgr	4.0	10	56.4	—2.1	+1.3	64	12	28.0	—2.3	—0.1	269
	23	i	Tau	5.1	1	0.1	—0.2	—2.8	137	1	46.5	—0.9	+0.1	230
	27	A^2	Cnc	5.7	1	33.9	—2.5	+0.6	67	2	26.5	—0.5	—3.2	340
	30	431	B.Leo	6.2	5	40.5	—1.3	—1.3	106	6	49.6	—0.9	—1.9	303

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′.

Apr.	2	p^5	Leo	5.4	11	28.6	—0.5	—0.5	68	12	10.5	—0.1	—2.4	334
	7	47	Lib	5.9	13	56.3	—2.0	—3.5	151	14	34.7	—0.3	+1.3	214
	8	131	B.Sco	5.6	8	17.0	—1.8	+2.1	66	9	20.8	—1.1	—0.7	317
	11	ρ	Sgr	4.0	10	1.7	—1.1	+1.6	80	11	21.8	—1.6	+1.0	269
	22	163	B.Tau	5.8	4	3.8	—0.2	—0.3	63	4	51.6	+0.5	—1.6	297
	30	431	B.Tau	6.2	5	4.8	—1.1	—2.2	153	6	11.6	—2.4	—0.4	266

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

In submitting the annual report for the American Meteor Society, I regret to say that the totals are low compared to some previous years. There are several reasons for this. First, the Perseid epoch in 1938 was greatly complicated by bright moonlight, so that fewer persons tried to observe and those who did saw only a fraction of the usual hourly number of meteors. Compared, for instance, with 1937, this alone meant 5000 less observations. Secondly, J. W. Simpson, who up to 1938 had, for a number of years, directed the Missouri-South Illinois group with conspicuous success, went off to college. As a result the known activity of the group dropped to nearly zero while in the previous seven years they had averaged over 5000 meteors annually. Again no general report has come from the Wisconsin-North Illinois group which used to be most active, nor from the Texas group, though we have many individual observations from that state. Of course, summations by the regional directors are often delayed and may yet arrive, but I do not feel that the annual report should be held up longer. We are encouraged, however, by many more members working in California and in New England, while some other state groups and many individuals have continued or increased their output of observations.

In Table I, when a large group reported or even when more than one person took part, to save space, only the name of the person who wrote appears. The letter g in the "Remarks" column indicates such was the case. With regard to fireballs, the 190 reported refer to the number of individual objects. Actually we have on hand, for many of these 190 fireballs, anywhere from 2 to perhaps 75 reports on a single object. It would be conservative to say that 400 people wrote in about them alone. H. J. Pruett, regional director for the West Coast States, and C. H. Smith, regional director for New York, have both been most active in collecting data on brilliant fireballs and personally working up their paths. Several such cases, sent here for final revision, remain unpublished due to my lack of help in this special type of work. Prof. Donald Faulkner of Stetson University, DeLand, Florida, had two coöperating parties at work on the Leonids, both of which had great success. He is now having the heights worked out by his classes.

The work of many other members, which was outstanding or unusually interesting, has from time to time had special mention in these Meteor Notes during recent months. Of the observations in Table I, not quite all were made in 1938, but include perhaps 300-400 from former years which were reported late. I should add it is inevitable that a report gets mislaid here occasionally, and so may not be found and included until later, without fault on the part of the observer. Table I contains meteors both counted and plotted; perhaps one half of the total were actually plotted.

We wish to welcome these new members, who have joined since the last list of additions to our ranks was published in April, 1938.

Robert Layton, 501 S. Chickasaw St., Pauls Valley, Oklahoma.
Gerald Pirsig, Route 2, Blue Earth, Minnesota.
Howard E. Boe, 2916 N. Lavergne Ave., Chicago, Illinois.
R. H. Glenney, 1231 McKinley Ave., San Antonio, Texas.
F. D. Silkey, 241 E. Rose St., Owatonna, Minnesota.
Earl Jessen, 423 Laurel St., San Francisco, California.
Elbert F. Ritter, 203 Gilmor St., Baltimore, Maryland.
Campbell McArthur, 72 Newbury Ave., N. Quincy, Massachusetts.
Herbert Rubinstein, 2703 E 4 St., Tucson, Arizona.
William Wallace, 1258 143rd St., E. Cleveland, Ohio.
Vernon Avery, Banks, North Dakota.
Fred E. Ellis, 71 Martin St., Cambridge, Massachusetts.
Betty Jane Thompson, 2021 Villard St., Eugene, Oregon.
Margery D. Jones, 2007 East End Ave., Pomona, California.
Vitaly Tresun, 1343 Thayer Ave., Los Angeles, California.
Kenneth Richter, 33 Clarence Ave., Bridgewater, Massachusetts.

To all our members who have paid their dues or sent in observations for 1938, we are about to mail *Reprint of the Flower Observatory* No. 46.

We wish to thank most sincerely those few members of the A.A.V.S.O. who are good enough to record and report the telescopic meteors they see. Why all members of that Society, as well as of other active amateur groups, cannot be induced to keep records of telescopic meteors, I do not know. It is a matter in which—with almost no trouble and no *extra observing* whatever—data of value can be collected. Another earnest appeal is made for coöperation in this matter. Proper blanks will gladly be sent to all who will use them.

To the Hydrographic Office, U.S.N., and to the U. S. Weather Bureau we are under continued and great obligations for their aid in securing data on fireballs. Their help is indeed invaluable. I further think it is only just to the University of Pennsylvania to remind our members that practically all the expenses of the A.M.S. are borne by it, through the Flower Observatory. In fact, the dues received would hardly do more than cover the annual postage bill of our Society. The securing of reprints of Meteor Notes, the maps, blanks, etc., distributed free to our members could never be financed by our dues, in which, incidentally, fully half of our membership are in arrears. It is well that we should all bear these facts in mind. Finally, to one and all I offer my thanks for their observations and, in many cases, for the inspiring of others to take part. We hope that better conditions of moonlight and weather will permit a far larger report for 1939 than we had in 1938. Also I request all to send in anything they have in the way of observation, whether few or many, so they may go into a supplementary report in the near future.

The National Geographic Society and Cornell University are sponsoring a program of research on the Aurora Borealis. I have readily agreed to suggest to members of the A.M.S. that they coöperate. Hence Professor C. W. Gartlein of Cornell University, Ithaca, New York, has sent me instructions and observing

blanks for distribution to some of our Society. I will be glad to have those interested in this worthy program write me if they care to take part. As aurorae are relatively infrequent in the United States, I do not believe this will take much time so there need not be undue hesitation on that score.

TABLE I

Observer and Station	Nights	Meteors	Remarks
Arslonian, L., San Jose, California	2	13	
Anyzeski, V., New Haven, Connecticut	6	95	
Avery, V., Banks, North Dakota	2	24	
Bennett, Miss D. A., New York City	5	160	g
Bowman, E. F., Kansas City, Missouri	1	45	
Dole, R. M., Cape Elizabeth, Maine	10	303	
Engle, R. R., Des Moines, Iowa	2	167	g
Euart, Providence, Rhode Island	2	238	g
Erickson, Mid-Atlantic	1	10	
Faulkner, D., DeLand, Florida	1	544	g
Glenney, R. H., San Antonio, Texas	2	44	g
Green, G., Pittsfield, Massachusetts	14	161	g
Jewett, Miss M. L., Grandview, Tennessee	1	19	
Khan, Mohd. A. R., Begumpet, India	52	840	
Larrabee, Miss L. M., Honolulu, T. H.	5	1074	g
Laskaris, L., Warren, Pennsylvania	3	75	g
Leerman, J., Baltimore, Maryland	6	91	
Loreta, E., Bologna, Italy	17	488	
McArthur, C., N. Quincy, Massachusetts	7	96	
Mastell, R., Hibbing, Minnesota	3	117	
Morris, W. R., Constantine, Michigan	11	240	
Neale, J. J., New Haven, Connecticut	13	138	
Olivier, C. P., Upper Darby, Pennsylvania	3	69	g
Page, T. J., Stamford, Connecticut	29	370	
Pirsig, G., Blue Earth, Minnesota	16	244	
Preucil, F., Joliet, Illinois	3	148	g
Ridley, G. W., San Francisco, California	12	512	
Shapinski, Miss M., Louisville, Kentucky	3	824	g
Smith, F. W., Thiells, New York	13	52	
Stackpole, H., San Jose, California	6	46	
Stone, W. R., Santa Barbara, California	15	214	
Sullens, J. L., West Plains, Missouri	2	83	
Whitney, B. S., Oklahoma City, Oklahoma	6	47	
Non-members in August		1362	
Fireballs		190	
Casuals		10	
Telescopic		90	
Total		9243	

TABLE II

TELESCOPIC METEORS

Observer and Station	No.
Kirkpatrick, G. P., New York City	26
Herbig, G., Elsinore, California	18
Jones, E. H., Goffstown, New Hampshire	15
Flower Observatory, Upper Darby, Pennsylvania	15
Chandra, R. G., Jessore, India	7
Callum, Wm., Chicago, Illinios	5
Neale, J. J., New Haven, Connecticut	1
Rademacher, Dr. E. S., Hamden, Connecticut	1
Rosebrugh, D. W., Poughkeepsie, New York	1
Wark, H. A., Cincinnati, Ohio	1
Total	90

Flower Observatory, Upper Darby, Pennsylvania, 1939 February 14.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
Department of Astronomy, University of California, Los Angeles

President of the Society: H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver
Secretary of the Society: ROBERT W. WEBB, Department of Geology, University of California, Los Angeles

The Willamette, Oregon, Meteorite in History*

By J. HUGH PRUETT,
University of Oregon, Eugene

Abstract.—In 1902, Ellis Hughes found the Willamette, Oregon, meteorite on a hillside near Oregon City. It was on property belonging to the Oregon Iron & Steel Company. Unable to buy the land, Hughes constructed a crude truck, loaded the 16-ton object onto it, and, by means of a windless and horse, secretly moved it three-quarters of a mile to his own house, after three months of work. There he exhibited it to the public for a fee of 25 cents. The company from whose land the meteorite was moved soon brought suit to recover it. The lower court awarded it to the company. Hughes appealed to the State Supreme Court, and, on July 17, 1905, the high court decided that such objects are real estate and belong to the land where they are found. The company then moved the already famous object to Portland, where it was exhibited at the Lewis and Clark Exposition. On February 15, 1906, Mrs. William Dodge II of New York bought the meteorite from the owners and presented it to the American Museum of Natural History in New York City. There it has since remained.

In the autumn of 1902, Ellis Hughes, a Welsh miner, accidentally discovered a large, partly buried rock on a hillside not far from his own property near Willamette, Oregon, just across the river from Oregon City. The next day, he and a neighbor, William Dale, examined the find. Striking it with a small stone, they found it rang like a bell. They decided definitely that it was a meteorite. The men learned that the land on which the meteorite lay was the property of the Oregon Iron and Steel Company. They covered the object with fir boughs and began to plan for the purchase of the land. Dale soon went to Eastern Oregon to try to sell some property he owned there in order that they might purchase the desired land. Dale either failed to sell his property or else decided to use his money otherwise. At any rate, he never returned to Willamette.

In the autumn of 1903, Hughes, urged by his wife, decided to move the meteorite from the place of its discovery to his own house, three-fourths of a mile away. He prepared a crude truck of logs with wheels made from cuts from a very round log. After considerable excavating and operation of jacks, he succeeded in getting the huge mass—it weighed over 31,000 pounds—onto his truck with the flat side down. (The flat side was uppermost when found.) Hughes next set up a "Spanish windlass" and anchored it securely about 100 feet from the truck. A horse was driven in an endless path around the windlass, while a steel

*An abridged form of a 4,000-word paper presented by Betty Jane Thompson at the Sixth Annual Meeting, Richmond, Virginia, December 29 and 30, 1938.

cable, one end fastened to the truck, was wound around the barrel of the windlass. Thus, with a relatively small force exerted by the horse, an immense pulling force was imparted to the cable. Then began the long haul. The ground was soft and even the wide wheels sank in. Boards for wheel-tracks had to be laid and relaid. Every time the 100-foot cable was wound onto the barrel of the windlass, the latter had to be moved another 100 feet toward the destination and securely re-anchored. Hughes was assisted by his 15-year-old son. Some days they succeeded in moving their precious load no more than the length of the truck. The best day they made less than 100 feet. But after three months of work in the forest (it is said that not even the nearest neighbors knew what was going on), the truck arrived beside Hughes's house. A rough shed was built over the prize and the announcement was made to the public that the meteorite would be exhibited for a fee of 25 cents.

The news spread and people came from far and near to view the visitor from the sky. As luck would have it, one who paid the 25-cent fee was the attorney for the Oregon Iron and Steel Company, owners of the land where the meteorite was found. The attorney offered Hughes $50 for it. The offer was promptly refused. Soon a court suit was started by the company for possession of the object. The court proceedings make very interesting reading. The defendant (Hughes) produced as witnesses old Indians who testified that, long before, their ancestors had owned the meteorite—they said it fell originally from the moon—and they had considered it a sacred stone. They dipped their arrows into the rain water which collected in the hollows on top in order that they might have success in their battles with distant tribes. Their young braves were initiated by being sent up onto the hill to the meteorite on the darkest of nights. The defense said further that the object had likely not fallen originally onto the spot where it was found by Hughes. It might have been an "erratic" and been carried there from some other locality on an ice floe, as had various chunks of granite in the vicinity, when the Pacific slope was long ago covered with water. It might have been found by the Indians at some lower elevation and in some way have been moved up the hill in order to give it a place of eminence. But the court considered that sufficient proof had not been produced to show that the object had not originally fallen onto the hill; so the decision was in favor of the plaintiff, the Oregon Iron and Steel Company.

Immediately the company started to move the meteorite from Hughes's property. Hughes then appealed to the State Supreme Court, and the crude truck and its load were left standing beside the road. The steel company hired a guard to prevent the theft of any pieces of their property until the decision of the higher court should be given.

Meanwhile a queer suit was instituted by the owner of the land which lay between Hughes's place and the hill where the meteorite was found. Hughes had to move his truck over this intervening property. The owner named both Hughes and the steel company as defendants and contended that neither was the rightful owner, since Hughes had found the object really on this third party's land. As proof, he showed a hole in the ground from which he said Hughes took the meteorite. But it was fairly definitely shown that he had blasted out this hole in order to put in a false claim. He lost his case. Now the recent co-defendants were free again to fly at each other. At last, the Supreme Court, on July 17, 1905, sustained the lower court, and Hughes gave up further claim to the noted object.

The meteorite was then taken by its owners to the Mines Building at the Lewis and Clark Exposition at Portland and there it was exhibited during the remaining weeks of the fair. A very ceremonious unveiling was carried out in the

presence of the governor of the state and other dignitaries. After the Exposition, it was hoped that the Willamette meteorite would remain in the state where it was found. But Mrs. William Dodge II of New York made a very tempting bid for its possession and bought it from the Oregon Iron and Steel Company on February 15, 1906. Mrs. Dodge at once presented it to the American Museum of Natural History. It was delivered to the Museum on April 14, 1906, and placed on exhibition on June 7 of the same year. There it has since remained.

In July, 1938, a party from the University of Oregon visited the locality where the meteorite was found. H. S. Crooker now operates a fox farm on the original site. The depression from which the object was taken is still undisturbed. Mr. Crooker has collected large amounts of the iron shale from the hole. The party was able to find a few pieces of this. Mr. Hughes, now 77 and very alert mentally, still lives in the locality and seemed very willing to be interviewed and photographed. But he is still very bitter over the court decisions and feels that there was no justice in them.

The "Tree Meteorite" of La Pine, Oregon*

By J. Hugh Pruett,
University of Oregon, Eugene

Abstract.—On August 16, 1938, the *Portland Oregonian* carried on its front page a story of the finding of a white-hot meteorite in a hole in a fir tree about 60 feet from the ground. It was said that it had cut through 14 inches of the side of the tree. The story spread all over the country. The writer saw it in *Time* and in the *Christian Science Monitor*. Attempts were made by interested persons to obtain samples for inspection, but the holder refused all requests. He would not let even newspaper men see it! Two forestry officials finally got a glimpse of it. They reported that it was light in color and weight and full of holes. It was soon learned through the Forestry Department that "tree meteorites" had several times previously been reported in the Pacific Northwest. Analyses of these objects had revealed a composition about like that of the ashes from sound wood in the same trees. Very little iron (only traces) and no nickel have been found. It is thought that these clinkers are formed when the top of a tree is burned off by forest fires and ashes sink down into the trunk, perhaps into a rotten spot, and there fuse into a solid mass by the intense heat of the surrounding burning wood.

On August 16, 1938, the *Portland Oregonian* carried the following news item on the front page:

"A meteorite, still white-hot, was found buried in the smoking hole in a large white fir tree near La Pine, Oregon, last Thursday by forest patrolmen of the Walker Range Patrol Association, it was reported by J. H. Haner, Secretary of the Association.

"Investigating a report of fire, the patrolmen found smoke issuing from the hole in a tree 60 feet from the ground. They felled the tree, and, on raking the fire out of the hole, found the glowing meteorite, described as the size of a ten-quart water-pail.

"The metallic mass, resembling smelter slag, had penetrated the wood to a depth of 14 inches and was shattered by the impact. Its course across the grain of the wood indicated that it had been traveling almost parallel to the earth's surface."

*An abridged form of a paper presented at the Sixth Annual Meeting.

A day or two later, an editorial in the same paper discussed the story at length without any seeming doubt as to its authenticity. The account spread over the country. It was published in such papers as the *Christian Science Monitor* and *Time* as a striking news item. The *Bend Bulletin*, a daily paper published near La Pine, attempted to get a sample to send to the University for inspection. The correspondent was not permitted even to see the precious specimen! Two national forestry officials, by some means, got a look at it a little later and reported to the Bend paper that they found it light in color and weight, and very porous. The *Bend Bulletin* then published an editorial which ended as follows:

"The La Pine fire-fighters may resent the intimation that the object they found in the fir tree, smoke from which was reported two weeks before the tree was cut down, was not a meteorite. They should not take this attitude. They will be doing science a real service by submitting samples of the stone-like object for study."

As a last resort, the present writer sent Mr. Haner postage for the mailing of a small sample to the University of Oregon, with the promise that every bit of it would be returned to him just as soon as an examination could be made. Mr. Haner was told that only three authenticated meteorites have ever been found in Oregon and that the Society for Research on Meteorites is ever on the alert to add a fourth. Soon a reply was received. The postage was returned. A copy of the offending Bend editorial was attached to a letter which ended:

"I note you say I could contribute to science *etc.* I am not interested in your work, and, because of the editorial, the 'clinker' will not again be exposed to the critical examination of any one, especially *college* men."!!

It seems that these objects are fairly well known to science. Forest-service literature contains frequent references to them. Thirteen years ago, Ranger Albert Baker of the Umatilla National Forest in northeastern Oregon reported he had found a meteorite burning high in a broken-off tree almost 60 feet from the ground. Thornton T. Munger, then Director of the Pacific Northwest Forest and Range Experiment Station, made this statement at the time:

"Every once in a while, somebody finds a lump or clinker in the remains of a snag that has been hollowed out by fire while standing. This stone-like stuff gives a chemical analysis strikingly like that of wood ashes. It looks as though, when a rotten tree burns while standing, the ashes go down with the fire and gather into a solidified clinker. Therefore, before blaming transient celestial bodies for setting trees afire, look into the possibility that the 'meteorite' is just a fused bunch of the tree's own ashes."

Last summer Mr. Munger wrote regarding the La Pine object that he did not think a meteorite was to blame, "but probably another heavenly body, a bolt of lightning." In the *Journal of Forestry* for May, 1929, Dr. Raymond Kienholz of the University of Illinois discusses the formation of these tree clinkers in considerable detail. He states:

"A seemingly necessary condition is a slow, smouldering fire, burning in a deep cavity where the supply of oxygen may be limited, forming an accumulation of ashes which will be fused into a slag-like mass by heat—during a later vigorous burning of the surrounding wood."

Analyses show considerable calcium and potassium oxides, very little iron, mere traces of silica, and no nickel. So it seems that Oregon meteorite-enthusiasts cannot list the La Pine "tree meteorite" as the fourth find in their state, but must be content to "worry along" with the number which has stood unchanged since the huge Willamette iron was found 36 years ago!

How the Casas Grandes, Chihuahua, Mexico, Meteorite got to Washington, D. C.

By Oscar E. Monnig,
312 W. Leuda St., Fort Worth, Texas

Abstract.—A quotation from the life story of August Santleben tells of his obtaining and transporting by wagon the Casas Grandes, Chihuahua, Mexico, iron meteorite of nearly 1¾ tons' weight. He took it from Chihuahua, *via* Ft. Davis, Ft. Stockton, and San Antonio, to Luling, Texas, whence it was shipped, apparently by rail and water (through Galveston), to the Centennial Exposition at Philadelphia, Pennsylvania. The account fills a gap in the history of the meteorite, throws some light on the conflicting stories of its early owners and possessors, and mentions the unique doctrine that all meteorites are the inherent property of the government and not subject to individual ownership.

The Casas Grandes, Chihuahua, Mexico, meteorite is noted by Farrington[1] as having conflicting stories about its discoverer and also the person into whose possession the mass came. (1) According to the early literature, Müller, of Chihuahua, Director of the Mint, found the meteorite in a labyrinthine room while excavating the temple ruins of Casas Grandes, in Chihuahua, and had possession of the mass in 1870. (2) Another account, apparently based mostly on letters from William M. Pierson, the United States Vice-Consul at El Paso, Texas, indicates that it was the Mexican inhabitants of the neighboring small town who searched the ancient temple ruins for treasure, and that one of their number, Teodoro Alverado, found the meteorite, wrapped like a mummy, in the middle of a large room. It was taken to the little town of Casas Grandes and placed in the street before the house of the finder, from whom Farrington says it was purchased years later, by Pierson and others.

The letter from Pierson (1873 or shortly before), quoted in Tassin's paper[2] on this meteorite, states that "Angerstein, Leroy, and myself have made up the necessary funds to purchase this rare and novel specimen, making it a mutual adventure . . . We shall have it safely lodged in the consulate within 15 days from this date." While the story which we are quoting hereafter does not conflict with the more likely version ascribing the original discovery to Alverado, it does seem that Pierson and his associates must not have realized their plans, for Müller was evidently the primary claimant when the main mass left Mexico; and it was still near Chihuahua, and not at El Paso, as late as 1875. Incidentally, it may be noted that Müller was not a government official, and did coinage work for the Mexican government on private contract.

It is well known that there have been all sorts of intrigues in connection with the ultimate disposition of many meteorites, and this fact is true especially of some of these earlier, large masses. The ownerships, claims, and transfers necessarily, or at least naturally, often became involved and disputed. No doubt a large part of the details of the chain of title of the Casas Grandes iron lies buried in state papers or correspondence; it is doubtful whether it would serve any useful purpose to unearth and publish the exact relations between the claims of Pierson and his associates and those of Müller, and how they were settled, even if such a thing could be done. But there is an interesting question as to just how the meteorite got to Washington, D. C. Farrington states that a piece of it came into the possession of the Smithsonian Institution in 1873, together with Pierson's report, and that "nothing further was heard from the mass till 1876, when the Smithsonian Institution came into the possession, by gift, of an uncut mass of meteor[it]ic iron,

which had been exhibited among the Mexican minerals at the Centennial Exposition" at Philadelphia. The hiatus in this respect is supplied largely in a book brought to our attention by Mr. F. M. Getzendaner of Uvalde, Texas, who kindly lent us his copy of *A Texas Pioneer,* by August Santleben (The Neal Publishing Co., New York and Washington, 1910). This volume is concerned with the author's life and adventures in the early days of the region between San Antonio and the border; Santleben transported considerable freight and money along a route between Mexico and Texas. Mr. Getzendaner has a most extensive knowledge and acquaintance of the country and the people in the Uvalde region, and states that he has found the book reliable as a whole. He knew the author's brother and from him and others who were acquainted with Santleben, is inclined to give full faith and credit to the general narrative. In Chapter XX, Santleben unfolds an interesting story; we quote from it in full in so far as it concerns this meteorite, and have *italicized* some incorrect statements on which we shall comment later:

"I was in Chihuahua again in the spring of 1875, and while there was told that several years before a large *aërolite had fallen on the ranch of Mr. Henry Mueller,* near San Lorenzo, about ten miles from the city, which was said to be one of the most massive known to the scientific world. I became very much interested in the subject and decided that if it was possible to secure the *stone* I would haul it to Texas and place it on exhibition at the World's Fair in Philadelphia.

"Legally, the meteorite belonged to the owner of the land on which it fell, and as Mr. Mueller attached no value to it, personally, he agreed to let me have it. But in the meantime the Mexican authorities had asserted a claim, based on the assumption that as it came from space it was not subject to individual ownership; consequently the Republic had a right to dispose of it in any way it pleased. These pretentions were not disputed by the owners, although it is obvious that they could not have been sustained; but it was useless for me to oppose them, and I determined to secure it from the government on the most favorable terms.

"The decision made it necessary for me to negotiate with the proper officials, and after I explained my intentions they graciously condescended to allow me to carry out my wishes under the following conditions, to which I subscribed: They permitted me to transport the meteor[it]ic *stone* out of the country free of export duty and to the Centennial Exposition buildings, at Philadelphia, at my own expense; but they required Mr. Mueller and myself to give a bond for a considerable amount, which stipulated that the *stone* should be safely returned to Chihuahua within a certain time without cost to the government.

"The meteorite was composed of solid iron and weighed *5400 pounds.* It was shaped like a turtle, round on top and flat below. It measured about two feet through its thickest part and curved to the edges, where it measured three feet wide and four feet long across the bottom. *Evidently when the mass of metal struck the earth it was soft enough to be flattened by the impact and retained the imprint of the solid rock where it fell among loose stones on the surface, which were imbedded in the lower part.*

"This visitant from another world was not very attractive in appearance, but I was fascinated by it and thought that others would be equally impressed when the curiosity was placed on exhibition. I was aware that it would be a difficult and costly undertaking, but I expected to consign it to one of the show places where sightseers would reimburse me for my trouble and outlay.

"I hauled the mass of iron on a wagon assigned for that purpose and it alone made a heavy load, which strained the team more than bulky freight would have

done, because it was dead weight in the bed and the wagon had no swing. The other wagons were loaded with heavy freight in the bodies, including $200,000 in silver coin, and a bulky top weight of hides, which caused them to oscillate with a motion that relieved the teams. At Forts Davis, Stockton, and Concho the *aërolite* attracted great attention among the soldiers, and when it arrived in San Antonio the wagon was unhitched and placed in the rear of the Veramendi House, which was then occupied by Mr. Weber, a brother of Jacob Weber, who resides on North Flores Street, where it was viewed by hundreds during the two weeks it was there.

". . . I got through with my train all right, but the meteor[it]ic *stone* caused a certain amount of trouble, and the expense was considerable, because the wagon carried nothing else . . .

"Luling [his destination] was then a new town that had sprung up in a few weeks at the terminus of the Galveston, Harrisburg, and San Antonio Railroad . .

"I left the *stone* in Luling with instructions to send it to Philadelphia, but as my business called me back to Chihuahua immediately, I was unable to give it further attention. It was publicly exposed with the Mexican exhibit without my authority, and my claim was ignored, as if the contract was not in existence. When the Centennial Exposition closed the meteorite was donated by Mexico to the *British Museum*.[1] The opportunity had passed when I might have made it profitable, and I was glad to be relieved of the expense and trouble that would otherwise have devolved on me had I been required to comply with the exactions of my agreement.

"The meteorite was my property under the contract until I was released from my bond, and I have never understood why it was taken from my possession and transferred to others without adequate compensation. Justice entitled me to a reimbursement of my actual outlay at least, and such generosity at my expense was inexcusable. As the matter now stands, individual acts, backed by the Mexican government, made me an involuntary contributor to science contrary to my expectations; and I will always believe that I have a claim resting against that *stone*, amounting to about five hundred and fifty dollars; but if proper credit was awarded for my services I might be willing to discharge the debt."

The meteorite is technically a *siderite* (*iron*) rather than an *aërolite* (*stone*), and the story that it had fallen several years before on Müller's ranch was false, as it is undoubtedly prehistoric. The weight was later ascertained to be only 3,407 pounds. The idea that the mass was in a molten state when it struck the ground is an old and common misconception; if there was any rock imbedded in the lower part of the iron, it was probably a water deposit of travertine which had become affixed to the meteorite before it was ever moved from its original place of fall.[2] However, Dr. W. F. Foshag of the United States National Museum, who kindly furnished us with a reprint of Tassin's original paper, writes that "The Casas Grandes iron meteorite does not now show any coating of travertine and if such was ever present it has been cleaned off." "British Museum" in the foregoing account is obviously an accidental error for "Smithsonian Institution."

References

[1] *Catalogue of the Meteorites of North America*, O. C. Farrington, *Mem. Nat. Acad. Sci.*, **13**, 111-12, 1915.

[2] "The Casas Grandes Meteorite," Wirt Tassin, *Proc. U. S. Nat. Mus.*, **25**, 69-74, 1902.

The Piñon, New Mexico, Siderite

By H. H. Nininger

Abstract.—The Piñon, New Mexico, siderite came into the writer's hands in May, 1932. The meteorite was a rather shapeless mass weighing about 17.85 kgs. (39¼ lbs.). It proved to be a nickel-rich ataxite, with a nickel content of 16.32%, according to a chemical analysis by F. G. Hawley, which is given in full. The meteorite is preserved chiefly in the State Agricultural College of New Mexico at Mesilla Park and in the Nininger Collection in Denver, Colorado.

The Piñon, New Mexico, Siderite
Weight: 17.85 kgs. (39¼ lbs.)

The subject of this paper, the Piñon, New Mexico, siderite, came into the hands of the writer in May, 1932, through the courtesy of the Department of Chemistry of the State Agricultural College of New Mexico at Mesilla Park. The specimen had been turned over to the Department by Mr. E. L. Stone, who reported that it had been found by a sheep-herder named Apolonio Garcia, in Tp. 19 S., Range 18 E., Sec. 22, Chaves County, New Mexico. This location is in lat. 32° 40′ N. and long. 105° 6′ W., just east of the Sacramento Mountains. The meteorite was a rather shapeless mass of weight about 17.85 kgs. (39¼ lbs.). The surface was somewhat pitted, but not strikingly so. The color was a dark, rusty-brown, but the specimen showed no great exposure to terrestrial weathering. In no place was there a heavy scale and in some places there appeared to be preserved portions of the original fusion crust, though in most places the color of the mass had been obscured by oxides. A small, wedge-shaped block had been sawed from one edge of the specimen; the exposed surface showed the meteorite to be a siderite of a compact structure. At a few other places, the bright metal protruded

through the brown coating of oxides in small projections. The meteorite was placed on the saw and cut through the middle. Cutting revealed a very nearly homogeneous structure with only a few small troilite inclusions and no fractures or indications of cleavage planes. Carefully selected sawings were submitted to Mr. F. G. Hawley for a chemical analysis. He reported the following results:

Chemical Analysis of the Piñon Siderite

Fe	82.52%
Ni	16.32
Co	0.67
Cu	0.03
Cr	0.019
Mn	trace
P	0.402
S	0.102
C	0.03
SiO_2	0.02
O	trace
Total	100.113
Pt metals	2.52 oz. per ton, or 0.0084%

Three items stand out in this analysis. It shows high content of nickel, phosphorus, and platinum. The Tlacotepec, Tecamachalco, Puebla, Mexico, siderite showed a similar high content of both nickel and platinum. The high nickel content of Piñon at once suggested its place among the ataxites. Etching of a polished section established its ataxitic relations. No lines or lamellae developed. The texture appeared very compact and notably structureless. There appeared spots and streaks having a reflective luster in a certain light. These spots were elongated, with more or less fringed edges, and their longest axes were all parallel; they could be seen only when the light arrived from a certain direction. Under a lens, the structure of the spots and streaks was not distinguishable from that of the surrounding mass. Strong etching gave to the surface a dark, velvety sheen, and any rubbing of this surface, even light rubbing with the finger, produced an ugly blemish of brush-like scratches. This blemish was believed to be due to the dislodgment of grains of rhabdite (schreibersite), which had been left in relief by the etching process. Apparently, the dislodged grains scratched the surface as they were dragged along by the finger or other agency. Microscopic examination of the etched surface revealed a very abundant distribution of rhabdite. This observation was in harmony with the high phosphorus content indicated by the chemical analysis. The rhabdite was in the form of needle-like crystals. While there was no definite arrangement of the rhabdite which lent itself to any system of crystallization, there seemed to be a strong tendency for a uniform orientation such that, when the light arrived from one given direction, the majority of the needles behaved like mirrors and imparted to the etched surface a very lively sheen. In this position the surface appeared under the lens to be studded with jewels.

The Piñon meteorite resembles most closely the Skookum Gulch, Klondike, Yukon, Canada, meteorite and is classed as a nickel-rich ataxite. Piñon is preserved chiefly in the State Agricultural College of New Mexico at Mesilla Park and in the Nininger Collection in Denver, Colorado.

Subsoil Meteorites* [Abstract]

By H. H. NININGER

A study has been made of 60 meteoritic falls, including 62 stones and irons which were recovered from below plow depth. It was found that no meteorite of more than 14 pounds' weight came to rest within reach of the plow, unless it landed on rock or on frozen ground.

Stones of wts. 15 lb. to 40 lb., av. 25.1 lb., reached an av. depth of 20 in.
Stones of wts. 40 lb. to 100 lb., av. 56.3 lb., reached an av. depth of 24 in.
Stones of wts. 100 lb. to 300 lb., av. 149.8 lb., reached an av. depth of 49 in.
Stones of wts. 300 lb. to 800 lb., av. 632.3 lb., reached an av. depth of 133 in.

Very few of the meteorites of more than 40 pounds' weight are ever found unless they are seen to strike the ground; yet 7.2 times as great a mass of material has been recovered from below plow depth as has been recovered from the upper 6 inches of the soil, according to the records of the falls studied.

The records were found to be very incomplete, and the plan of search used in connection with these falls is known to have been very inadequate, so that generally only a small part of each fall is thought to have been recovered. However, the ratio between the mass of material recovered from the cultivation layer of the soil and from the subsoil in this group of falls was applied to the results of a survey, conducted by the writer, which is now in the beginning of its sixteenth year. This survey is concerned with the recovery of unwitnessed falls. We have grouped our finds into the same size-groups as was done with the recoveries from the 60 falls studied, and applied the inter-group ratios there established. By comparisons between areas intensively searched and those in which only a general effort has been made, an estimate was arrived at concerning the amount of material in the subsoil of an area of 150,000 square miles, of the great plains adjacent to Denver, Colorado. This estimate is 7260.7 tons. On this basis, 164,290 tons should have been deposited in the subsoil of the entire United States during the period represented by the accumulation of the material which we have collected. This period is estimated roughly at 100 years. During the same period, 9,535,477 tons of meteorites of weights between 15 lb. and 800 lb., should have arrived on the entire planet. At this rate, in 60 million years, since the beginning of Tertiary time, there would have been added to the earth, 5,721,286,386,000 tons of meteoritic material, or enough to compose a layer 2.8 mm. in thickness over the whole earth. It is fully realized that these estimates are based upon inadequate data. However, the survey is being continued, and the preceding estimates are regarded merely as tentative.

*Read at the Sixth Annual Meeting.

The S.R.M. Made an "Affiliated Society" of the A.A.A.S. and a Representative Appointed to the Council of the Association

In a letter dated January 10, 1939, to Secretary Robert W. Webb, Dr. F. R. Moulton, the Permanent Secretary of the American Association for the Advancement of Science and a Councilor of this Society since its inception, writes:

"I am very happy to inform you that on December 30, 1938, the Council of the Association, on recommendation of its Executive Committee, voted to admit the Society for Research on Meteorites as an affiliated society of the A.A.A.S.

"You are undoubtedly aware that this change in status of the Society for Re-

search on Meteorites entitles it to representation on the Council of the Association. I should appreciate it if you would appoint a representative to the Council and notify me of the appointment."

The Executive Committee of the Council of the Society has appointed Dr. Lincoln La Paz, of the Department of Mathematics of the Ohio State University, Columbus, as the representative of the S.R.M. in the Council of the A.A.A.S.

The S.R.M. was founded in August, 1933, and incorporated, under the laws of the State of California, in July, 1936. In April, 1935, when it was less than two years old, it was accepted as an "associated society" of the A.A.A.S., in conjunction with conventions of which it has held its Second, Third, Fifth, and Sixth Meetings. By the recent (December, 1938) action of the Council of the A.A.A.S., the Society has been promoted to full affiliation status in the Association. The only other astronomical organizations which are affiliated (or associated) with the A.A.A.S., are the Astronomical Society of the Pacific (founded in 1889) and the American Astronomical Society (founded in 1899).

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Frequency of Types and Distribution of Variable Stars: A tabulation, according to type, of nearly 8200 variable stars listed in the 1939 Schneller catalogue of variable stars has recently been made at the A.A.V.S.O. headquarters. It reveals some interesting facts concerning the distribution of the several types of variation as well as the number of variables found in different constellations. Although such a list must of necessity be subject to considerable "selective" error, yet it is significant that there is apparently little agreement between the number of variables and the prevailing areal distribution of stars, whether characteristically sparse or numerous. Variable star workers have laid stress in recent years on particular sections of the sky, notably in photographic surveys of Milky Way Regions; so that what appear in the present tabulation to be salient distributional features may or may not be confirmed when a more exhaustive examination of the whole sky has been made and a still more nearly complete catalogue thus becomes available for discussion.

It is to be noted that Schneller's catalogue contains only those stars which have been recognized as variable by the Astronomische Gesellschaft and assigned letters or numbers, and does not include numerous stars pronounced as variable by other reliable authorities. This situation has come about because the conditions under which stars were to be considered as entitled to a place in the catalogue have not been entirely complied with: additional information is required in order to classify the stars as to type, amplitude, period, etc. Variables found in globular clusters or in external galaxies are not, as a rule, included.

In making the original tabulation, each star listed in the Gesellschaft catalogue was considered as belonging to one of several classes (in the main those assigned by Schneller): Cepheid, eclipsing binary, long-period, U Geminorum, Z Camelop-

ardalis, R Coronae Borealis, nova, N Type, RV Tauri, irregular, semi-regular, short-period, stars now considered to be non-variable, and those of unknown type. The stars were then grouped according to type within each constellation, and the type-totals reduced to percentages of the whole number of variables per constellation. For further purposes of comparison, the areas of the constellations were reduced approximately to percentages of the whole sky on the basis of a total area of 41,253 square degrees.

The total number of variables listed is 8177, of which 52 are classed as probably not variable, and 1205 as of unknown type. In the tabulation of the percentage of the total number of variables found in each class for separate constellations these two groups were not included. In the entire sky, Cepheids numbered 21 per cent, and eclipsing variables 20 per cent. By far the greatest number, 2707, or 39 per cent of the whole, are found to be long-period variables. It is to be noted that these three classes comprise 80 per cent of all the variables of known class, and that the stars of irregular-type total another 9 per cent, leaving only 11 per cent to be included in the remaining classes. Curiously enough, these ratios hold well for many sections of the sky, especially in the larger constellations where many variables have been found. According to this compilation, stars of the U Geminorum and R Coronae Borealis types average about 6 or 7 to a thousand variables—probably a high value, because these two classes contain some stars which should belong more properly to other classes; novae and nova-like stars constitute 1.5 per cent, and stars of N spectra total 1.9 per cent. The smallest class proves to be the Z Camelopardalis type stars, which will doubtless be increased somewhat in proportion as the number of U Geminorum type is decreased.

The largest constellations, even in the Milky Way, do not appear to contain the greatest number of variables, nor the smallest constellations, the fewest. For example, Sagittarius, covering 1.8 per cent of the sky, has 9 per cent of the variables, whereas Cygnus, with an area of 2.3 per cent, has only 5.1 per cent. Scorpius, nearly as large as Sagittarius, has only six-tenths as many variables.

Caelum, one of the smallest constellations, has only three variables, whereas Ara of nearly equal area contains 248 variables. The location of Ara with reference to the galactic plane (and hence greater observational attention paid to it) may be the controlling factor in this relation; closer study of Caelum may perhaps reveal a larger number of variables within its boundaries.

Although long-period stars appear to outnumber other types in almost every constellation, notable exceptions are Carina, in which 15 per cent are long-period, 23 per cent Cepheid, and 43 per cent eclipsing; and Canes Venatici, which has 50 per cent Cepheid to 23 per cent long-period. There are relatively few variables listed in the latter constellation—a total of only 23.

In the abridged table given here, the abbreviation of the constellation is followed by percentage of the area in terms of the whole sky, the percentages for the three predominating types—Cepheid, eclipsing, and long-period variables—together with the total number of variables, percentages of variables in terms of the whole, galactic latitude for the approximate centers, and frequency of variables per unit area.

The greatest frequency per unit area proves to be Corona Austrina, with a value of 10.0, and Triangulum Australe, with 9.0, whereas the smallest are Grus, with 0.08 and Reticulum, with 0.10.

Constellation	Percentage				No. Vars.	% Vars.	Gal. Lat.	Freq. Vars.
	Area	Cep.	Ecl.	L-P				
And	2.2	9	20	40	76	0.93	−27°	0.42
Ant	0.7	19	19	23	36	0.44	+19	0.63
Aps	0.5	29	12	36	42	0.52	−12	1.04
Aqr	2.2	37	19	25	136	1.7	−51	0.77
Aql	1.6	14	10	53	450	5.5	−10	3.44
Ara	0.6	22	17	51	248	3.0	−11	5.00
Ari	1.2	18	12	47	18	0.22	−38	0.18
Aur	2.0	11	25	33	127	1.6	+10	0.80
Boo	1.5	29	26	23	37	0.45	+61	0.30
Cae	0.3	0	0	33	3	0.04	−39	0.13
Cam	1.2	21	13	42	39	0.48	+28	0.40
Cnc	1.2	17	30	27	34	0.42	+37	0.35
CVn	1.2	50	9	23	23	0.28	+77	0.23
CMa	1.2	27	37	24	44	0.54	− 5	0.45
CMi	0.4	8	27	37	51	0.62	+14	1.55
Cap	1.2	30	9	39	52	0.63	−37	0.52
Car	1.0	32	43	15	205	2.5	− 1	2.50
Cas	1.4	23	25	25	123	1.5	− 2	1.07
Cen	3.0	22	35	28	409	5.0	+16	1.67
Cep	1.5	12	25	37	75	0.92	+11	0.61
Cet	3.1	2	2	4	30	0.36	−70	0.12
Cha	0.4	0	0	100	4	0.05	−19	0.12
Cir	0.2	11	23	56	69	0.84	− 4	4.20
Col	0.7	0	2	6	10	0.12	−26	0.17
Com	0.8	74	17	9	27	0.33	+82	0.41
CrA	0.3	45	9	33	241	3.0	−17	10.00
CrB	0.5	12	25	38	19	0.24	+49	0.48
Crv	0.5	0	0	57	8	0.10	+47	0.20
Crt	0.9	25	25	25	9	0.11	+42	0.12
Cru	0.2	26	59	10	64	0.78	+ 2	3.90
Cyg	2.3	11	25	43	421	5.1	+ 2	2.22
Del	0.4	7	24	43	97	1.2	−18	3.00
Dor	0.4	33	9	42	19	0.23	−36	0.58
Dra	1.9	13	20	42	55	0.67	+29	0.35
Equ	0.2	0	50	25	6	0.07	−29	0.35
Eri	2.5	23	28	23	78	0.95	−41	0.38
For	1.0	45	28	11	19	0.23	−61	0.23
Gem	1.4	12	32	32	94	1.1	+13	0.79
Gru	1.1	0	50	50	7	0.09	−53	0.08
Her	3.1	12	17	47	196	2.4	+32	0.78
Hor	0.5	0	0	100	11	0.14	−55	0.28
Hya	3.3	12	24	29	81	1.0	+23	0.33
Hyi	0.9	48	21	14	30	0.36	−43	0.40
Ind	0.6	0	9	58	15	0.18	−44	0.30
Lac	0.4	8	28	27	123	1.5	−12	3.75
Leo	2.2	33	23	26	39	0.48	+55	0.22
LMi	0.5	50	13	25	8	0.10	+57	0.20
Lep	0.7	9	33	33	12	0.15	−24	0.21
Lib	1.4	21	13	61	44	0.54	+36	0.39
Lup	0.7	11	6	65	119	1.5	+12	2.14
Lyn	1.2	0	9	58	13	0.16	+31	0.13
Lyr	0.6	12	16	46	181	2.2	+15	3.67
Men	0.5	50	0	25	6	0.07	−30	0.14
Mic	0.6	0	0	100	9	0.11	−41	0.18
Mon	1.0	13	30	30	96	1.2	+ 4	1.20
Mus	0.4	21	33	30	91	1.1	− 8	2.75
Nor	0.4	17	35	30	226	2.8	0	7.00
Oct	0.6	21	0	58	29	0.35	−32	0.58
Oph	2.4	20	11	51	520	6.4	+17	2.67
Ori	1.6	9	31	22	187	2.3	−12	1.44
Pav	1.0	30	16	42	72	0.88	−27	0.88
Peg	2.6	19	25	38	142	1.7	−35	0.65

Constellation	Area	Percentage Cep.	Ecl.	L-P	No. Vars.	% Vars.	Gal. Lat.	Freq. Vars.
Per	1.6	17	17	26	100	1.2	—10	0.75
Phe	1.4	17	11	50	21	0.26	—69	0.18
Pic	0.6	0	33	33	13	0.16	—32	0.27
Psc	1.9	15	15	30	29	0.35	—46	0.18
PsA	0.7	10	40	20	13	0.16	—56	0.23
Pup	1.7	31	32	21	86	1.1	— 3	0.65
Pyx	1.0	16	11	42	20	0.25	+13	0.25
Ret	0.2	0	0	50	2	0.02	—44	0.10
Sge	0.2	13	16	41	41	0.50	— 2	2.50
Sgr	2.1	37	10	40	737	9.0	—16	4.29
Sco	1.4	12	6	68	455	5.6	+ 2	4.00
Scl	1.3	24	12	52	37	0.4	—87	0.30
Sct	0.3	34	22	35	110	1.3	— 6	4.33
Ser	1.0	21	14	51	85	1.0	+41	1.00
Sex	0.8	29	0	14	7	0.09	+42	0.11
Tau	1.9	14	18	27	96	1.2	—20	0.63
Tel	0.6	0	0	63	32	0.39	—23	0.65
Tri	0.4	9	27	45	12	0.15	—29	0.38
TrA	0.2	33	13	33	148	1.8	— 8	9.00
Tuc	0.6	44	4	36	51	0.63	—50	1.05
UMa	3.1	14	20	31	39	0.48	+57	0.15
UMi	0.8	11	11	67	9	0.11	+35	0.14
Vel	1.2	28	38	18	86	1.1	+ 3	0.92
Vir	3.3	27	14	28	86	1.1	+59	0.33
Vol	0.4	0	20	80	7	0.09	—23	0.22
Vul	0.8	12	30	39	100	1.2	— 6	1.50
Totals		21	20	39	8177			

The Peculiar Variables: R Coronae Borealis appears to be slowly increasing in light after having reached a minimum at magnitude 13.6. On January 20 the star had attained magnitude 12.3. Nothing is known concerning the activity of RY Sagittarii since the last report. SU Tauri and S Apodis are presumably at maximum. Mount Wilson Observatory reports that SU Tauri was at photographic magnitude 17.1 on September 25, 1938.

SS Cygni passed through a period of abnormality in December, ending with a short-type normal maximum early in January. U Geminorum has been at minimum since October, 1938. SS Aurigae presented a long and a short type of maximum, the former early in November and the latter about December 20. The rise to maximum each time was remarkably well observed. The behavior of RX Andromedae—a star of the Z Camelopardalis type—has been decidedly erratic during the past eight months. Since early in May, 1938, there was an almost complete absence of the usual short-term period until September. Even during September as well as in subsequent months, few well-defined maxima were observed, the star remaining at or near the twelfth magnitude with only slight fluctuations in light. Z Camelopardalis itself appears to have maintained its expected form of variation.

Nova Herculis, 1934, continues to decrease slowly in light, having reached the ninth magnitude in January. Nova Lacertae, 1936, has dropped to about the thirteenth magnitude.

Observers and Observations during January, 1939: Major M. A. Dávila of Mexico City, Mexico, contributes an initial report. The Astronomisk Selskab of Copenhagen, Denmark, contributed 128 observations of SS Cygni made by its members during the year 1938, thus supplying valuable material for dates on which the star was previously recorded as unobserved.

Observer	Var.	Est.	Observer	Var.	Est.
Adamopoulos	2	2	Kearons	54	89
Ahnert	39	102	Kelly	15	30
Albrecht	8	12	Kirkpatrick	24	69
Baldwin	93	215	de Kock	48	207
Ball, A. R.	12	14	Loreta	151	433
Blunck	7	7	Lundquist	4	21
Bouton	52	90	Maupome	33	33
Brocchi	17	17	McLeod	35	66
Callum	28	28	Millard	9	10
Carpenter	8	8	Neale	3	3
Chandra	199	424	Needham	20	20
Cilley	29	42	Parker	16	19
Cousins	31	90	Peterson	1	3
Dafter	10	26	Peltier	100	123
Dávila	35	35	Purdy	.14	20
Davis	4	5	Radamacher	4	4
Diedrich	16	16	Recinsky	8	14
Ellis	3	6	Rosebrugh	19	57
Economou	25	51	de Roy	16	72
Escalante	100	125	Russell	4	4
Fernald	26	47	Seely	13	20
Focas	55	95	Sill	12	12
Halbach	24	24	Slocum	4	4
Hartmann	150	246	Smith, F. P.	10	18
Herbig	153	617	Smith, L.	5	5
Hildom	28	43	Topham	4	4
Holt	86	99	Webb	27	27
Houghton	69	181	Weber	25	25
Houston	18	27	Woods	7	27
Irland	11	11	Yamasaki	27	29
Jones	70	193			
			Total observations		4187

February 15, 1939.

Comet Notes

By G. VAN BIESBROECK

COMET 1939 *a*. The first comet of the year 1939 was found on the evening of Janury 19 by two independent observers: in this country the first report came from Leslie C. Peltier, the variable star observer and comet hunter of Delphos, Ohio. This is the seventh comet that he has discovered with the 6-inch refractor which he has made famous. But, as on several previous occasions, he shares honors with another observer; since on the same night, only a few hours earlier due to the difference in longitude, the comet was reported also by Kosik of the Tashkent Observatory in Turkestan. This astronomer is known in comet literature as one of the co-discoverers of COMET 1936 *b*.

The new object, the magnitude of which was given as 8 by the discoverers, was immediately observed in various localities and already by January 23 a first orbit was available. Several preliminary orbits were published, differing only slightly from each other. We give here a more nearly accurate parabolic orbit computed by A. D. Maxwell at Ann Arbor from the measures covering a ten-day interval to January 31.

ELEMENTS OF COMET KOSIK-PELTIER (1939 *a*)

Date of Perihelion	1939 Feb. 6.85676 U.T.
Longitude of node	288° 41′ 48″.0
Node to perihelion	169 1 25.8
Inclination	63 32 44.9
Perihelion distance	0.716381 astronomical units

They indicate that the maximum brightness occurred around February 10. The orbit is highly inclined showing that the comet must have been visible for some time before discovery. After it was found in Cygnus the comet moved southeastward across Pegasus. The following ephemeris results from the elements given above.

EPHEMERIS OF COMET 1939 *a*

1939	α h m	δ ° ′	M
Feb. 26	1 15.3	—21 17	6.8
Mar. 2	2 34.7	25 56	7.2
6	2 55.4	29 42	7.6
10	3 12.0	32 45	8.0
Mar. 14	3 27.0	—35 15	8.4

The magnitude is given under the assumption that the maximum brightness was $6^{M}.0$ on February 10.

Unfavorable weather and the presence of the full moon have hampered observations here. However, on February 10 the total intensity was estimated as $6^{M}.2$ with a binocular, the instrument being slightly out of focus so as to facilitate comparison with stars of known brightness. During the first days the head of the comet was not more than 2′ in diameter; in its center shone a bright nucleus, the diameter of which was not larger than 0′.3 as seen in the 40-inch refractor. The most conspicuous feature was a fairly bright tail pointing away from the sun.

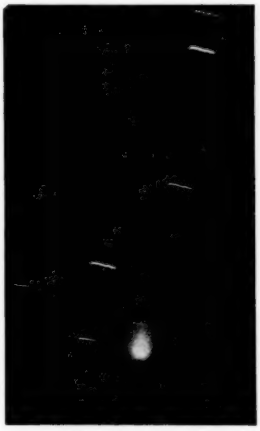

FIGURE 1

Figure 1 is an enlargement of a 20-minute exposure obtained here on January 23 with the 24-inch reflector. The plate was made to follow the motion so as to bring out the details. The fainter extension of the tail is lost in the reproduction but on the original plate it can be traced to more than a degree from the nucleus. By the time the present issue is distributed northern observers will have lost sight of this fugitive object, which is moving rapidly southward as indicated by the ephemeris.

In the course of 1939 we expect the return of several faint periodic comets:

(a) COMET KOPFF which comes to perihelion about March 12 is still too close

to the sun for observers on this side of the equator.

(b) COMET BORRELLY, which comes nearest to the sun this summer, is most unfavorably situated at that time but it might perhaps be found earlier; the following ephemeris by A. C. D. Crommelin shows it should be looked for in the evening.

EPHEMERIS OF COMET BORRELLY

1939		α h m	δ ° ′
Feb.	26	0 16.3	−19 49
Mar.	6	34.6	16 54
	14	0 53.1	13 54
	22	1 12.0	10 46
Mar.	30	1 31.2	− 7 37

(c) The conditions will be more favorable for PERIODIC COMET PONS-WINNECKE which is due nearest to the sun about June 26. According to the computations by A. E. Levin and J. C. Porter the search may already be successful in March by using the following ephemeris:

1939		α h m	δ ° ′
Mar.	6	14 21.0	+27 45
	14	29.8	30 25
	22	37.3	33 17
	30	43.5	36 14
Apr.	7	14 43.0	+39 8

Williams Bay, Wisconsin, February 11, 1939.

Notes from Amateurs

New Haven Amateur Astronomical Society

The evening of February 4 was a busy and profitable one for the members of the New Haven Amateur Astronomical Society.

At 7:15 P.M. a group of about twenty met at the Yale Observatory and viewed the Kosik-Peltier comet through the 9-inch Reed refractor.

At 8:00 P.M. Mr. Knapp (one of our members) gave a very interesting talk on Jupiter and by means of blackboard sketches and lantern slides made a very fine presentation. He stated that, the axis of Jupiter being more nearly perpendicular to the plane of the ecliptic than that of any other planet, only 3.1 degrees, there can be but little changes in its seasons.

Jupiter is also larger than all the other planets put together, but while its bulk is 1340 times that of the earth, its mass or the matter that it contains is only 316 times that of the earth.

The discovery of the four satellites of Jupiter by Galileo in 1610 showed the planet as a miniature solar system encircled by satellites which was a vindication of the "Sun Center" theory advanced by Copernicus which was discredited by the false but universally believed "Earth Center" theory.

Mr. Knapp spoke at length concerning the great rose-colored spot between its belts south of the equator that made its appearance in 1878, which was 8000 miles wide by 35,000 miles long. The next year it changed to brick red, then gray and of late it has assumed a pinkish color. Four earths in a line could have been placed in its area, but it is now reduced to 6300 miles by 19,500 miles long. Its true nature is still in doubt.

The meeting adjourned at 9:15 P.M. and twenty-six members drove the four miles to the home of the secretary where the Telescope Makers Group provided instructive entertainment for the remainder of the evening in the form of constructive criticism of a number of mirrors in process of polishing and figuring with demonstrations of the technique of using the pitch lap to correct errors and zones. While this was being explained and shown, one of the members demonstrated the complete method of aligning a 6-inch reflector to assure the proper positions of mirror, prism, and eyepiece in relation to the axis of the tube. This demonstration was upon a telescope recently completed by one of our members, and the method employed was simple, scientific, and accurate and required practically no equipment (other than easily made) and about one hour's time.

New Haven, Connecticut. F. B. BURNHAM.

Jupiter in 1938

During the year of 1937 the writer observed the great planet Jupiter in the southern sky much to his enjoyment. In 1938 similar observations were made, but with the increased experience obtained from observing the previous year, and the results seemed so interesting that it was thought that other observers might enjoy reading about them.

It might be said, in beginning, that opposition this year occurred on August 21 with the declination on that date equal to —14°. The greatest angular diameter was 49".0. Thus, due to the low declination, the "seeing" was with one or two exceptions never very good. The methods of studying Jupiter which the amateur can use are: (1) transit work to determine the longitudes and changes in longitude of various marks on the "surface" of the planet, (2) the making of drawings, and (3) color observations. The first type of observation is quite the most important, and probably deserves some explanation. Jupiter rotates in a period of about 9 hours, 55 minutes, as given in textbooks. But this planet, like the sun, rotates fastest at its equator, the center of the bright band called the equatorial zone. Outside this zone, the rotation period is slower. The equatorial regions rotate in an adopted standard period of 9 hours, 50 minutes, 30.0 seconds, which has been named System I longitude. The regions to the north and south rotate in an adopted standard period of 9 hours, 55 minutes, 40.6 seconds, System II longitude. Assuming these periods, tables of longitudes for each System are published every year giving the longitude seen central on the disk of the planet for 0^h, G.C.T. In obtaining the longitude of a marking in the planet's atmosphere, therefore, the observer notes the time to the nearest minute when the mark transits the central meridian (appearing central between the limbs of the planet), and with suitable tables the longitude is easily worked out.

During his own work, which was chiefly that of obtaining transits, the writer had the pleasure of corresponding with several other observers who were also interested in Jupiter. They are the following: F. L. Frazine, St. Petersburg, Florida, 12-inch reflector; W. H. Haas, Alliance, Ohio, 10-inch refractor and 6-inch reflector; D. R. Sliwinski, Toledo, Ohio, 6-inch reflector; J. R. Smith, Smyer, Texas, 8-inch reflector; Latimer J. Wilson, Nashville, Tennessee, 12-inch reflector. Mr. Wilson is an experienced observer of Mars and Jupiter with many years of observation to his credit. He is doing, besides the regular visual transit work, a type of work usually, if not previously entirely, done by the professional only: making a regular series of photographs of Jupiter and measuring longitudes of various marks from them. The results obtained by Mr. Wilson are *excellent*, considering the size of the telescope used.

The number of transits obtained by all six observers totalled over one thousand, with Mr. Wilson as leader with about one-half the total.

Probably the most interesting thing that happened on Jupiter during 1937 and 1938 was the transformation of the dark Red Spot of 1937 into the fairly bright Red Spot Hollow of this year, accompanied by the return of the dark matter of the South Tropical Disturbance. Both these marks are in the S. Trop. Zone of Jupiter. The Great Red Spot is perhaps the best known of all marks on the great planet. It has a long and interesting history, first having created widespread attention in 1878. Dawes is said to have seen it in 1857, and some observers have suggested that a similar spot seen in 1664 by Hooke and Cassini may have been the present mark. The transformation of the dark Red Spot usually seen in the normally bright S. Trop. Zone to the light Hollow seen in 1938 is not a new type of change. It was seen also in 1919-1920 and 1928 by other observers.

Now the Red Spot, as well as practically all marks, does not follow exactly the system of longitude to which it belongs (II). It is by following these drifts in longitude, and by using suitable tables that the rotation periods of various marks can be determined in fact. Obviously, if a spot does follow the system of longitude to which it belongs, remaining stationary in longitude, it has a period of rotation which is the same as its System. If a spot increases in longitude, its rotation perior is longer than its System; if it decreases, its period is shorter. Normally, the Red Spot very slowly decreases in longitude (II) a few degrees per year in longitude, having an average rotation period of 9 hours, 55 minutes, 37 seconds. However, it has at times rotated very slowly comparatively, and 1936-38 has been such a time. Especially this year we have a good example. Note the following longitudes (by System II), which are for the center of the Hollow:

July 1, 140°.0 August 1, 144°.2 September 1, 147°.8
October 1, 147°.3 November 1, 147°.4

These longitudes were obtained by plotting 18 transits by Wilson, 12 by Johnson, 5 by Smith, 4 by Haas, and 2 by Sliwinski on graph paper with dates and longitudes as coöordinates—as is usually done in Jovian work for any mark or group of marks—dividing the 41 transits into four groups of equal number, taking the mean longitude for each group, and drawing a smooth curve through the points of means.

With regard to the appearance of the Hollow itself, the following brief description might be of interest. The length was found (mean) to be 26°.5. In 1937 the length of the dark Spot was 23°.0 in longitude. The Hollow was oval in shape and of light or bright tone, as mentioned previously. It was not as bright as some of the ephemeral equatorial zone white spots. Curving around the preceding and following ends were curious dark bands, the following band marking approximately the following end of the whole S. Trop. Disturbance. Therefore the Hollow was located in the surrounding dark matter of the Disturbance. The narrow dark South Temperate Belt bounding the south edge of the Hollow was slightly darkened where it touched the Hollow. The South Equatorial Belt to the north of the Hollow was notched out for the oval, an appearance usually observed.

The preceding end of the S. Trop. Disturbance, that is, the preceding concave end of the dark matter in the normally white S. Trop. Zone, decreased in longitude (II) as it normally does. The following longitudes, obtained by 36 transits in the same manner as those given for the R.S.H., show the drift for this preceding end:

June 1, 283°.5 July 1, 277°.7 August 1, 271°.5
September 1, 267°.7 October 1, 267°.0 November 1, 266°.5

Contrary to these drifts, other ephemeral marks in the dark matter of the Disturbance seemed to increase fairly rapidly in longitude. But in any case, one notices a curious and possibly significant coincidence of the motions of the widely separated, in longitude, marks known as the Red Spot and the S. Trop. Disturbance. Both marks, until August 20, were moving rapidly with regard to their System of longitude, II, but on that date or very near it both marks change their rates considerably and follow II more nearly. The color of the dark matter was dusky purple or blue.

On the north edge of the North Equatorial Belt in +14° latitude two dark elongated spots were observed a total of about 95 times for transits by all six observers. They were observed over such long periods of time that the mean rotation period that they gave, 9 hours, 55 minutes, 13.4 seconds, is probably very nearly exact. It is doubtful if they had periods of rotation differing from each other at all, because unavoidable errors of observation could have caused the 0.8 second difference computed.

Turning now to equatorial zone marks, it is a much more difficult, or rather uncertain, task when rotation periods are to be found than when working out periods for isolated marks such as the Red Spot Hollow. This is due to the fact that Equatorial Zone spots are ephemeral, more numerous, and more irregular than other spots, generally. One's graph sheet becomes covered with observations, and it is a matter of care to choose the true drifts. The general appearance of the Equatorial Zone was quite different this year from that of 1937. The tawny color was even more pronounced this year, which is very unusual, and many more marks were seen. Last year, in 1937, white spots were small and scarce, being seen next to the North Equatorial Belt on the north edge of the Equatorial Zone. Also, they were generally seen better than while near the limbs, fading out as they approached the meridian. This year the opposite effect was seen, the white spots and other marks being seen best on the meridian. Equatorial Zone white spots were seen brightest and largest in July this year when, for two or three weeks they formed conspicuous chains of white ovals on the southern part of their tawny zone. After August they became irregular, smaller, and in general fainter. From both the equatorial dark belts, on either side of the Equatorial Zone, dark streaks pushed into the zone between the white spots, some making complete bridges across the zone. Those white spots which showed definite drifts on the chart gave a mean rotation period of 9 hours, 51 minutes, 11 seconds, with all of these in quite good agreement with the mean. However, unfortunately, most of the 1938 Equatorial Zone marks gave no definite indication of their motions, for the reasons previously explained, but Mr. Wilson thought that spots *in general* in this region drifted slowly toward increasing longitude (I) from 0° to about 165°, remained practically stationary from 165° to 240°, and decreased slowly from 240° to 360°. This is an interesting development if proved true.

In determining rotational periods to the nearest second or tenth second it may be questioned whether the apparently rough eye-estimation method of determining longitudes allows of such close determinations. To one who first looks at Jupiter, no rotational movement may be noticed in as much as ten or fifteen minutes. But to the experienced observer such a motion is quite visible in two or three minutes at favorable times, and he can usually note the time when a mark appears central quite accurately. Mr. B. M. Peek, Director of the Jupiter Section of the British Astronomical Association, says in *The Observatory* for September, 1936: "Jupiter's rotation is so rapid that with practice the error [of determining the time a mark is central] should seldom exceed two minutes, while an error of as much as

five minutes should be rare." To make actual comparisons with this statement, the writer went through all the transits of all the observers, excluding Mr. Wilson's work which was partly photographic, and found 28 transits by separate observers where duplication had occurred on the same mark at (theoretically if observations were perfect) the same time. The mean difference or residual + or — was 3.7 minutes which equals 2°3 longitude. Largest residual was ten minutes (6°1). In 14% of the duplicates, no residual occurred. Now, if we regard the true longitude of a mark as the mean between any two duplicates, which is quite reasonable, we may divide all the results above by two, cutting individual errors to 1.9 minutes to 5.0 minutes, nicely confirming Mr. Peek's statements. Thus if the period of observation on a spot is extended over a period of from one to six months, very accurate periods of rotation can be found. Another interesting thing found in checking over transits of Frazine, Smith, and Johnson, was that, when transits of the preceding end, center, and following end of a mark had been obtained, almost invariably the longitude for the "center" of the mark was not the mean of the longitudes of the ends, but was "shifted" by a small amount from the mean between the ends toward the following end. This probably really means that some systematic error is made on the ends of the marks, rather than on the centers.

Colors on Jupiter are interesting in themselves, and the subject of their changes is quite important. The tawny aspect of the Equatorial Zone was sometimes thought by the writer to have a definite olive hue. The other bright zones were dull white or light yellow. The dark South Polar regions were greenish gray this year, quite definitely different from the purple or violet tinge seen in 1937. The North Polar regions changed in a very similar way. Color observations made here were chiefly for Mr. Haas, who is very much interested in the subject of planetary and lunar color changes. This observer made an excellent series of observations of the relative intensities of the dark Jovian belts. In 1937 the North Equatorial Belt was undisputed leader among the belts. Again in 1938 this tendency continued, for, according to Haas' work between March 24-25 and October 30-31, this belt was first about 75% of the time. The South Equatorial Belt and the South Temperate Belt vied for second place, with the South Equatorial Belt nearly equal to the North Equatorial Belt till July, after which time it faded considerably. The South Equatorial Belt and North Temperate Belt often fell into third place, while the South Temperate Belt often occupied fourth position in rank. Only occasionally did Haas see the South South Temperate or North North Temperate Belts.

From the writer's measures on Mr. Wilson's photographs of 1938, the latitude of the center of the North Equatorial Belt was about +11°5, while the latitude of the center of the South Equatorial Belt was —11°5. The latitude of the center of the North Temperate Belt was +28°0; the South Temperate Belt's latitude being equal to —28°0.

The telescope used by the writer was the same as was used in 1937, a 5-inch diaphragmed 7-inch mirror of 59 inches focal length. The power used almost entirely throughout was 177×. Only on two occasions this year, a May morning, and July 15 at 1:25 A.M., C.S.T., did I have what might be called "perfect" seeing. On the latter date the planet's limb was perfectly sharp and detail was wonderful. Even the satellites with 177× were seen in their true form, extremely minute sharp disks of varying sizes. No person can describe completely such a scene!

HUGH M. JOHNSON.

3207 Cornell Street, Des Moines, Iowa, December 3, 1938.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editors may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

Planetary Rotation

Some interesting relationships between Keplerian elements and the rotational speeds of primaries of all the planet-satellite systems can be shown through two simple formulae.

s — planetary equatorial speed of rotation.
r — radius of planet.
R — radius of sun.
d — planetary distance in ordinary length units.
v — planetary orbital velocity.
u — orbital velocity of theoretical Keplerian body revolving around planet's surface in the plane of the equator.
t — periodic time of the theoretical Keplerian body revolving around planet's surface.
T — periodic time of theoretical Keplerian body revolving around the sun's equatorial surface (about 10,000 seconds).

Equation 1. $u(r/R)^{1/2} \times (t/T)^{3/4} = s$

E.g., Earth:
(mile/sec.) $4.9(4{,}000/432{,}000)^{1/2} \times (5{,}100/10{,}000)^{3/4} = .288\pm$ m.p.s.

Equation 2. $v(d/r)^{1/2} \times (r/R)^{2} \times (T/t)^{1/4} = s$

E.g., Earth: (mile/sec.)
$18.5(93{,}000{,}000/4{,}000)^{1/2} \times (4{,}000/432{,}000)^{2} \times (10{,}000/5{,}100)^{1/4} = .287\pm$ m.p.s.

In mile/second units planetary equatorial speeds are as follows:

Planet	Observed	Calculated
Earth	.289	.288
Mars	.15	.11
Jupiter	8.0	8.6
Saturn	5.9	5.85
Uranus ?	2.5	1.9
Neptune ?	1.75	1.8

Mars' rate may be affected by the exceptional case of its nearest satellite having a shorter revolutionary period than the planet's rotational period. Phobos, with orbital velocity of 1.35 m.p.s. and distant less than one diameter of the primary, might accelerate the latter's rotation. All orbital velocities and rotational speeds fluctuate more or less, so that all figures are necessarily approximate.

Time factors were derived through Kepler's third law and as Mercury and Venus have no satellites upon which to base such calculations they are not tabulated. However, if gravitational mass ratios are used with the formulae, the rotational speed for Mercury comes out about .06 mile/sec. and for Venus about .265 mile/sec.

Elements used in the calculations are as follows (mile/second):

Planet	Orb. vel.	Radius	Distance (million mi.)	Per. time Kep. body at surf. &	4th root of same
Earth	18.5	4,000	93	5,100 sec.	8.45
Mars	14.9	2,160	141	6,000	8.8
Jupiter	8.1	44,000	483	10,600	10.15
Saturn	5.9	36,000	885	14,900	11.
Uranus	4.3	16,000	1780	10,800	10.2
Neptune	3.7	15,500	2850	9,600	9.9
Sun		432,000		10,000	10.
Mercury	29.7	1,500	36	6,500	9.
Venus	21.8	3,850	67	5,400	8.6

C. O'CONNOR.

San Mateo, California, January, 1939.

General Notes

Dr. Frank Schlesinger, director of the Yale University Observatory, has been elected a member of the Royal Society of Sciences of Upsala. He has also been elected correspondent of the French Bureau des Longitude in succession to George Ellery Hale.

The Rittenhouse Astronomical Society of Philadelphia held a meeting on Friday, February 10, at 8:00 P.M., in the Hall of The Franklin Institute. The program was an illustrated lecture on the subject, "Testing the Astrological Fallacy," by Dr. J. Allen Hynek, Astronomer, The Perkins Observatory of Ohio State University.

Harvard Summer Conference on Astronomy

Between July 5 and August 15 the fourth series of Summer Conferences on Astronomy will be held at the Harvard Observatory. During the six-week period of the conferences the regular staff of the Harvard Observatory will be supplemented by distinguished visiting astronomers. It is hoped that many astronomers will take advantage of the splendid opportunities for guidance and research that are offered during the period of the Conferences. Visitors who wish to make use of the plate collection or the instrumental equipment of the Observatory will be accommodated to the greatest possible extent.

Dr. Svein Rosseland, Director of the Institute of Theoretical Astrophysics, Oslo, will lecture on Stellar Structure and Stellar Variation—the application of atomic physics and modern hydrodynamical theory to the internal structure of the stars and the variability of their light. Dr. J. H. Oort, of the University Observatory, Leiden, will discuss the Distribution and Motion of the Stars—the distribution of stars in high galactic latitudes, the density distribution on the plane of the galaxy, galactic rotation and the dynamics of spiral structure. A Survey of Modern Problems in Celestial Mechanics will be given by Professor E. F. Freundlich, formerly of Potsdam and Istanbul, now Professor of Astronomy at the University of Prague. Dr. Freundlich will discuss recent advances in classical celestial mechanics and some of the dynamical problems of star clusters and galaxies.

Dr. Shapley will be in charge of the informal discussions of current astronomical topics at the Hollow Square Conferences. The Conference on Special Problems offers a diversity of subjects: Dr. Menzel will consider the problems of the chromosphere; Dr. Brian O'Brien, Professor of Physiological Optics at

the University of Rochester, will discuss solar radiation and its influences on the earth's upper atmosphere; Dr. Zdenek Kopal, of the University of Prague, will present a treatment of eclipsing binaries with special reference to stellar structure; and Dr. Watson will consider the astronomical significance of small solid bodies.

Opportunity for guided research will be provided by Dr. Bok on Stellar Statistics, Dr. Menzel and Dr. Sterne on Astrophysics, Dr. Whipple on Meteors, Dr. Kopal on Eclipsing Binaries, and Dr. Dimitroff on Photoelectric Photometry. An elementary course on stellar astronomy, given by Dr. Freeman D. Miller of Denison University, will deal with the general characteristics of stars, star clusters, and galaxies and with problems in astrophysics.

Through special arrangement with the Summer School exceptionally low rates for auditing privileges can be offered. For details see the forthcoming circular or inquire of the Harvard Observatory.

Book Reviews

Who's Who in the Moon. *Memoirs of the British Astronomical Association*, Vol. 34, Part I, 1938. (Neill and Co., Edinburgh. $1.25.)

As its first memoir, the Historical Section of the British Astronomical Association has published a valuable directory of the 672 recognized named lunar formations. For the 609 persons for whom features are named, biographical sketches appear. Based upon the authoritative list compiled for the I.A.U. in 1935, by Mary Blagg and K. Müller, this 130-page work appears under the name of Mrs. John Evershed, the Director of the Historical Section.

The authorities for the names number twenty-five, ranging in time from the seventeenth century to the present day. Indeed, it comes as a surprise that there are ten craters named for living persons (Andel, Blagg, Darney, Delmotte, Fauth, Lamech, Mary Proctor, Ritchey, Hugh Percy Wilkins, Arthur Stanley Williams) and there are three others named for persons who have died only this year (E. W. Brown, Walter Goodacre, and W. H. Pickering). American personalities are well represented by Agassiz, G. P. Bond, W. C. Bond, E. W. Brown, Burnham, Henry Draper, Benjamin Franklin, B. A. Gould, Asaph Hall, Holden, Elisha Kane, James Lick, Matthew Maury, Maria Mitchell, Newcomb, B. O. Peirce, E. Pickering, W. H. Pickering, Ritchey, Lewis Rutherford, and Yerkes. Of these, Brown, Newcomb, and Agassiz were foreign-born, but their great work was done in America.

For each such named feature, the full and correct name of the person is given, with the dates of birth and death, or a date when he "flourished," if more accurate information is unknown. The authority for the name appears, and six or seven well-composed lines of biographical material. The number and location on the accompanying key map enables any formation to be identified. This key map, incidentally, is not extremely well done, but perhaps it will be found sufficient.

An even more interesting map is Riccioli's, of 1651, which is reproduced. On it is based our present lunar nomenclature, although Langrenus earlier had begun the practice of naming the craters for philosophers and other learned men. The ancients (explained Riccioli) are at the north, the "moderns" at the south; Plato and his friends and pupils are placed together, Tycho is accompanied by his disciples. Later naming has destroyed some of this scheme.

A few errors appear, but these can be spotted at once, for the most part. Under "Fraunhofer," the "Dorpat reflector" is mentioned, when refractor is obvi-

viously intended; under "Galle," the value of the solar parallax obtained in 1873 from observations of Flora is given as 88".87, the decimal point being misplaced; under "Otto Struve" (1819-1905), the date of accession of his namesake grandson to the directorship of the Yerkes Observatory is given as 1921, a decade too early; although in the introduction it is stated (p. 5) that the "total of 672" named features is treated, the last named, "Zupus," is only 671. There are doubtless many more slips, as indeed there are bound to be in a work of this sort, but surely it will prove to be interesting and valuable to all who are interested in the history of science.

ROY K. MARSHALL.

Wilson College, Chambersburg, Pennsylvania, December, 1938.

Katalog und Ephemeriden Veränderlicher Sterne für 1939, by H. Schneller. (Ferd. Dummlers Verlagsbuchhandlung, Berlin.)

The issue of this important compendium of information relating to variable stars, for 1939, was at hand in ample time. Although it is labeled as one of the smaller publications of the Berlin-Babelsberg Observatory, it has grown to be a full-sized volume, this issue being a volume of 256 closely packed pages of condensed data. This is an important aid to the work now being done in this extensive field of astronomy.

Stellar Dynamics, by W. M. Smart. (Cambridge University Press, 1938. 433 pages. £1-11s.)

This book by Professor Smart of the University of Glasgow fills a need which has been felt by many people who have not had the opportunity of following the development of stellar statistics and dynamics. Many textbooks have been written about the constitution of the sun and the stars and about the properties of stellar atmospheres, but very few about the problem of the motion of the stars within the galaxy, although the extensive research of stellar proper motions and radial velocities, which has been proceeding for many decades, primarily was supposed to give us an understanding of the properties and the dynamics of the galactic system of stars. The book covers much the same field as van der Pahlen's textbook, *Lehrbuch der Stellarstatistik,* which appeared last year.

In the introduction of the book is a general description of the astronomical terms, the general properties of the error function, and of the methods of correcting series of observed data. Then the author describes the statistics of stellar motions in terms of a single drift, of two star streams, and of the ellipsoidal distribution function. This part of statistical astronomy has probably never been explained in such detail, although the more general forms of distribution functions are not described. The results from proper motions and radial velocities are given in some detail, the author himself having done much work on the analysis of proper motion data on the basis of the two-stream theory.

The methods of computing mean parallaxes from parallactic motion and from π-component are given in much detail; in particular is the effect of the distribution of the stars over the face of the sky carefully studied. The formulae for total proper motions are also derived following the method of Kapteyn and van Rhijn.

The next chapter deals with the space distribution of the stars derived from their proper motions, a chapter which gives the derivation of many formulae scattered in many publications. Next come the general theorems of stellar statistics, largely based on Schwarzschild's solutions of the integral equations involved.

The motions of star clusters are described, and the effect of space absorption is introduced in this connection. The theories for the dynamics of star clusters are briefly stated.

The last three chapters deal with the dynamics of stellar systems in general, the galactic rotation, and the dynamics of the galaxy. Oort's and Lindblad's theories, as well as Milne's general kinematics, are fully explained.

It is a book which can be heartily recommended to those engaged in stellar statistics, a subject which has been somewhat neglected for the more exciting science of astrophysics. After all, we want to know something about the galaxy as a whole and not only of what goes on within the stars and their atmospheres.

GUSTAF STRÖMBERG.

Himmelswunder im Feldstecher, by Rudolf Brandt. (Johann Ambrosius Barth, Leipzig, Germany. 3.60 marks.)

The Wonders of the Heavens as seen through a Field Glass is the meaning of the above title. It pertains to a paper-bound brochure of about ninety pages, clearly and simply written, relating to the more conspicuous of the heavenly bodies. There are numerous photographs and drawings to supplement the verbal descriptions. One section is devoted to each of the following topics: Field Glass; A Temporary Observatory; The Sun; The Moon; The Planets; The Comets; Meteors; The Fixed Stars; The Eye.

The evident purpose of the book is stated in the final sentence in the Preface, as follows: "The purpose of the book will be fulfilled, if many, who possess field glasses, through them become friends of the wonders in the sky above us."

Publications of the Astronomical Observatory, University of Minnesota. (The University of Minnesota Press, Minneapolis, Minnesota.)

Bruce Proper Motion Survey: I. First Report; II. A Catalogue of 2350 Variable Stars Found with the Blink Microscope, both by William J. Luyten, constitute numbers 5 and 6 of volume II of the series mentioned above. In the first part, an eight-page pamphlet, the author explains the project and the procedure. This report is of special importance in that it pertains to the stars in the southern sky, which up to the last decade or two had not been given the same detailed study as the northern sky. The magnitude of the undertaking is strikingly indicated by the fact that "about 4000 hours were spent at the blink microscope. It is estimated that about 25,000,000 stars passed in review during this time." During the progress of this work some 75,000 stars with appreciable motion were detected. The second part, a 44-page brochure, lists the variable stars which were discovered as a by-product. These are included in the list of Harvard Variables, since they were found on Harvard plates. These stars are arranged in the order of right ascension, and the magnitude limits are given.

These pamphlets may be purchased from the publisher at fifty cents each.

Asteroid Notes.—No asteroid notes were at hand for this issue but will be continued in the April issue as usual.

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